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# CONCEPTUAL DESIGN OF MULTIPURPOSE DETENTION FACILITIES FOR FLOOD PROTECTION AND NONPOINT SOURCE POLLUTION CONTROL

by

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# PROJECT SUMMARY

The objectives of this effort were to evaluate alternative detention basin design characteristics to supplement the District's existing flood assessment practices in order to evaluate **both** flood levels and nonpoint load reductions, and associated benefits, for newly proposed and designed detention facilities. Our overall approach to this project was to use a comprehensive watershed hydrology and water quality model to evaluate the impacts on flood peaks, nonpoint source loads, and concentrations of selected water quality constituents under alternative detention basin configurations applied to a test watershed within Santa Clara County. The goals were to determine and quantify the likely impacts of detention basins (DBs) designed solely for flood control, and then evaluate the additional impacts if these DBs were modified to reduce nonpoint source loads and improve water quality.

In conjunction with District staff, the Calabazas Creek Watershed was selected as the test watershed based on a series of selection criteria, including land use, soils, and topography representative of Santa Clara County, and availability of rainfall, streamflow and water quality data for model application. The U.S. EPA Hydrologic Simulation Program - FORTRAN (HSPF) was selected as the watershed model because it is considered the most comprehensive watershed hydrology and water quality model currently available.

HSPF was calibrated to the Calabazas Creek watershed, and then a series of model scenarios were developed and simulated in order to evaluate the potential impacts of detention on both flood control and water quality. In conjunction with District staff, four alternative scenarios were defined. First, a scenario of detention basins designed solely for flood control in Calabazas Creek was simulated. Then, three additional scenarios were developed to superimpose changes in the detention basins to increase detention time for nonpoint source load attenuation and water quality improvement, and then focus on drainage from impervious areas which are major nonpoint sources. A baseline condition, without detention, was also simulated in order to have a framework, or basis, for comparing potential impacts of each modeled scenario. Thus, the following five conditions were implemented within the model and simulated:

- Baseline Conditions
- Flood Control Scenario
- Flood Control plus Permanent Water Quality Pool
- Flood Control plus Permanent Water Quality Pool and Extended Detention
- Flood Control plus Permanent Water Quality Pool and Extended Detention draining primarily impervious areas

For each scenario, 50-year simulations were performed with the HSPF model of Calabazas Creek, and flows, water quality concentrations, and loads were output and analyzed at various locations in the watershed. In addition, for each detention basin simulated, input and output loads were analyzed to assess the removal efficiencies implemented in the simulation.

The Calabazas Creek Watershed model based on the U.S. EPA HSPF program provides a sound and viable representation of the dynamic watershed behavior of hydrology, sediment, copper, and BOD loadings and concentrations. The model results demonstrated a capability to reproduce flows and concentrations that spanned the range and mimicked the dynamic nature of the watershed as shown by the observed data.

Based on our watershed and DB modeling investigations, and our review of the literature, it is apparent that the District should consider the impacts of newly proposed and designed DBs on nonpoint loads and water quality. To this end we recommend the following procedures and conceptual criteria for all new facilities:

a. The potential impacts of the proposed DB design on nonpoint load reduction should be assessed, and credit should be given in terms of load reductions to the Bay. The amount of reduction will depend on both DB design and operating characteristics, and pollutant characteristics. Removal efficiencies for metals should not be based on sediment removal values as this will tend to over-estimate actual metal removal of a DB.

b. Alternative longer detention times, from 12 to 60 hours or more should be assessed to determine the additional load reductions and water quality benefits that may accrue. The longer times must also be evaluated in terms of negative impacts for flood control such as lesser reductions of peak flows. Alternative design and landscaping should be encouraged by the District to consider potential multiple uses of such facilities.

c. The flood control and water quality impacts of proposed DBs need to be evaluated at both the local scale (i.e. at the outlet of the DB), and at the watershed scale. Impacts, such as changes in flood peaks and pollutant concentrations, may be small or negligible if less than 10% to 20% of the watershed is controlled by DBs. However, these impacts will be greater if additional DBs are approved and constructed within the watershed.

d. Since DBs are essentially 'treatment' options for reducing urban nonpoint pollutant loads, they should be evaluated in conjunction with 'source control' options that reduce the generation of nonpoint loads. Although source controls were not a focus of this study, our model simulations showed that water quality is very sensitive to local nonpoint loads. Comprehensive pollution control approaches, with both treatment and source control components, need to be evaluated at both the local and watershed scales. The District should consider watershed modeling as a tool for this type of comprehensive pollution control and management.

The Calabazas Creek Watershed model provides a capability for investigating a wide range of additional scenarios and alternatives for both DB design and watershed-scale impacts. To help further refine the study conclusions and recommendations, the report provides additional suggestions for further studies and refinement of the modeling assessment.

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# SECTION 1.0

# INTRODUCTION

## 1.1 BACKGROUND AND STUDY OBJECTIVES

The Santa Clara Valley Water District (District) is evaluating technical design criteria and operating procedures for potential multipurpose detention/retention facilities to achieve flood control, nonpoint source pollution control, and water quality improvement and associated benefits. The District is primarily responsible for flood control and water supply, but it is also a lead agency in protecting water quality in Santa Clara County.

The District has been preparing a Hydrology Manual of design criteria and procedures for evaluating flood frequency, flood volumes, and flood levels under pre- and post-development conditions, along with the impacts of detention facilities. In order to consider the water quality impacts and other potential benefits of the facilities, the District contracted with AQUA TERRA Consultants to investigate conceptual design criteria and procedures to assess the expected nonpoint source load reductions and evaluate potential tradeoffs between flood control and water quality benefits. These supplemental criteria and procedures may be used to assess alternative facility designs and their associated integrated benefits for flood control and water quality improvement. Potential benefits for recreation and environmental purposes may also accrue from well designed detention basins, but these potential benefits were not evaluated in this effort.

The District has long-established practices and procedures for flood assessment (Saah and Watson, 1976) including design guidance for detention basins. The objectives of this effort are to investigate alternative detention basin design characteristics to allow the District to consider the impacts of newly proposed and designed detention facilities on **both** flood levels and nonpoint load reductions.

## 1.2 OVERVIEW OF TECHNICAL APPROACH

Our overall approach to this project was to use a comprehensive watershed hydrology and water quality model to evaluate the impacts on flood peaks, nonpoint source loads, and concentrations of selected water quality constituents under alternative detention basin configurations applied to a test watershed within Santa Clara County. The goals were to determine and quantify the likely impacts of detention basins (DBs) designed solely for flood control, and then evaluate the additional impacts if these DBs were modified to reduce nonpoint source loads and improve water quality.

In conjunction with District staff, the Calabazas Creek Watershed (Figure 1.1) was selected as the test watershed based on a series of selection criteria, including land use, soils, and topography representative of Santa Clara County, and availability of rainfall, streamflow and water quality data for model application. The U.S. EPA Hydrologic Simulation Program - FORTRAN (HSPF) Bicknell et al, 1996) was selected as the watershed model because it is considered the most comprehensive watershed hydrology and water quality model currently available, it simulates both nonpoint loads and instream water quality processes, it includes the flexibility to simulate both urban and rural areas, and it allows representation of DBs and their water quality processes. Moreover, the authors are intimately familiar with the operation and application of HSPF, being involved in its development and application for more than 15 years, thus avoiding the time and cost associated with learning a new model.

To demonstrate the water quality impacts of detention basins, we modeled copper, sediment, and BOD with HSPF, including both nonpoint loads and instream processes impacting the fate, transport, and resulting concentrations and loads of these constituents in Calabazas Creek. Copper was elected as the primary metal of concern based on a recent review by Woodward-Clyde Consultants (1996b), and sediment was selected because it is a primary transport mode for copper, in addition to being a pollutant itself. BOD was selected to represent non-conservative pollutants that undergo losses through both settling to the channel bed and transformation/decay mechanisms. Ideally, nutrients (e.g. nitrate, ammonia, phosphate, total nitrogen, total phosphorus) would also be simulated due to their impact on water quality, but project resources and lack of available data limited the scope of the modeling effort. BOD was considered a surrogate for the likely range of impacts of DBs on nutrient loads.

HSPF was calibrated to the Calabazas Creek watershed, and then a series of model scenarios were developed and simulated in order to evaluate the potential impacts of detention on both flood control and water quality. In conjunction with District staff, four alternative scenarios were defined. First, a scenario of detention basins designed solely for flood control in Calabazas Creek was simulated. Then, three additional scenarios were developed to superimpose changes in the detention basins to increase detention time for nonpoint load attenuation and water quality improvement, and then focus on drainage from impervious areas which are major sources. A baseline condition, without detention, was also simulated in order to have a framework, or basis, for comparing potential impacts of each modeled scenario. Thus, the following five conditions were implemented within the model and simulated:

- Baseline Conditions **(BC)**
- Flood Control Scenario **(FC)**
- Flood Control plus Permanent Water Quality Pool **(WQP)**
- Flood Control plus Permanent Water Quality Pool and Extended Detention **(WQP/ED)**
- Flood Control plus Permanent Water Quality Pool and Extended Detention draining primarily impervious areas **(WQP/EDI)**

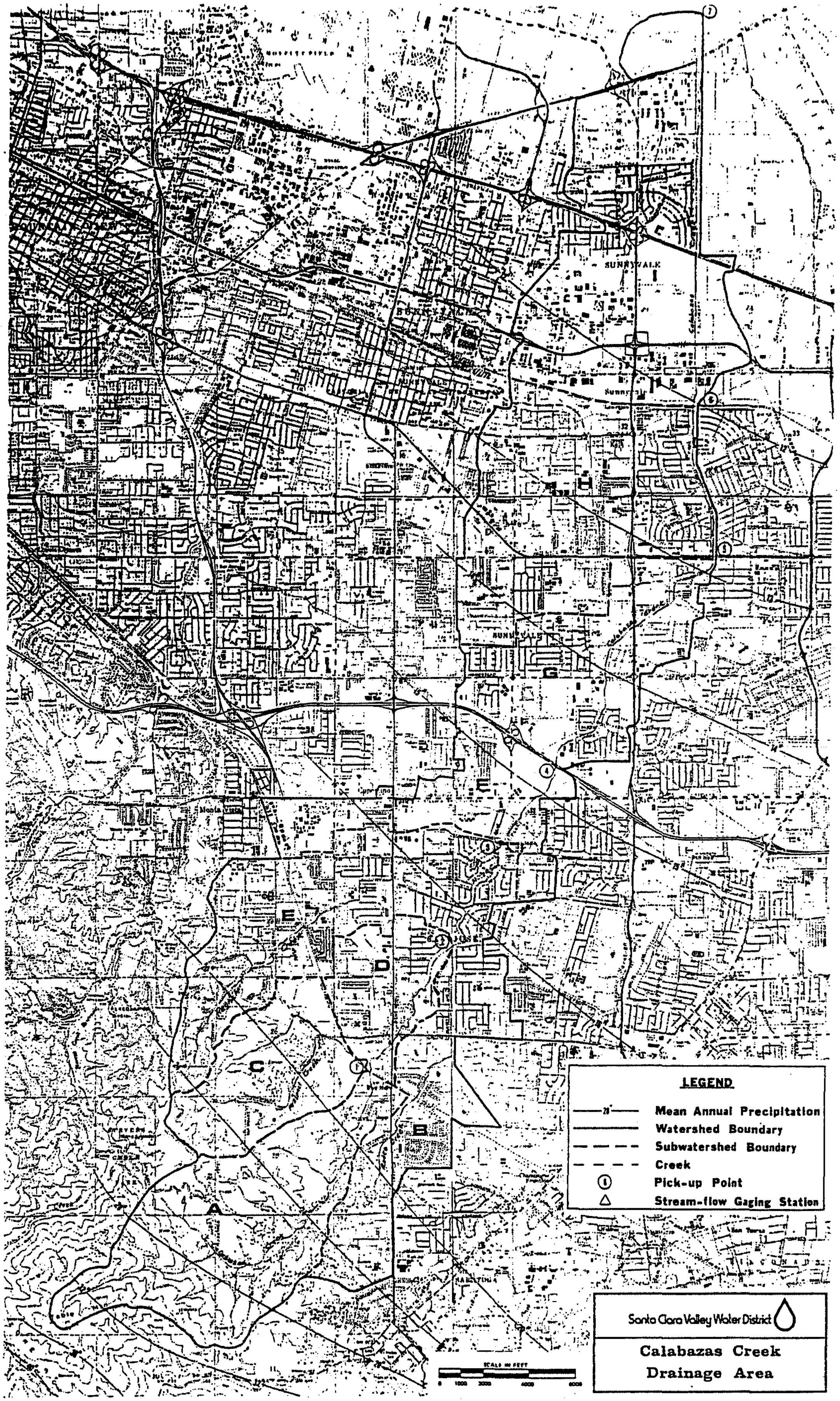

Figure 1.1 Calabazas Creek Watershed

For each scenario, 50-year simulations were performed with the HSPF model of Calabazas Creek, and flows, water quality concentrations, and pollutant loads (i.e. sediment, copper, BOD) were output and analyzed at both the Rainbow and Wilcox High School gage locations. In addition, for each detention basin simulated, input loads to the basin and output loads from the basin were analyzed to assess the removal efficiencies implemented in the simulation. Note that the **BOLD** designations (i.e. **BC, FC, WQP, WQP/ED,WQP/EDI**) above will be used in our discussions of these scenarios.

## 1.3 STUDY CONCLUSIONS AND RECOMMENDATIONS

The Calabazas Creek Watershed model based on the U.S. EPA HSPF program provides a sound and viable representation of the dynamic watershed behavior of hydrology, sediment, copper, and BOD loadings and concentrations. The model was calibrated and verified for hydrology for a 10-year period, and calibrated for the water quality constituents for a five-year period. The model was run continuously over these time periods with the primary focus on representing daily flows and storm event mean concentrations. The model results demonstrated a capability to reproduce flows and concentrations that spanned the range and mimicked the dynamic nature of the watershed as shown by the observed data.

### 1.3.1 STUDY CONCLUSIONS

Through the model application process described in this report, the HSPF model of the Calabazas Creek Watershed demonstrates the representation needed to evaluate likely impacts of alternative detention scenarios on both hydrology and water quality. Based on the model results for both the Baseline Condition and the Water Quality detention scenarios simulated for the Calabazas Creek Watershed, the following study conclusions are presented:

a. Detention basins designed primarily for flood control can provide complementary and significant water quality benefits through settling and decay of pollutants due to the added detention time.

b. Detention times, in the range of at least 12 to 48 hours, can provide significant reductions for both flood peaks and pollutant loads. However, the degree of flood peak reduction diminishes with longer detention times. Further studies should be conducted to evaluate impacts of both shorter (e.g. 4 to 8 hours) and longer (e.g. 3 to 7 days) detention times.

c. The degree of pollutant load reduction by detention basins depends on the characteristics of the specific pollutants of concern. In our simulations, the largest reductions were demonstrated for BOD which undergoes losses by both settling and decay; removal percentages for BOD showed a mean of 48% and a range of 32% to 65%. Other nonconservative constituents, such as nutrients, can be expected to behave in a similar manner with losses increasing with longer detention times.

d. Our simulations of conservative pollutants, such as sediment and copper, indicated the following conclusions:

   i. Sediment and copper demonstrated mean removals of 35% and 29%, respectively, with ranges of 16% to 62%, and 12% to 53%.

   ii. For sediment, the DBs settled all the sand particles and a portion of the silt and clay; these fine particle fractions are sensitive to the settling velocity parameters in the model.

   iii. Although copper is transported primarily on sediment, it also desorbs back into the overlying water after it has settled to the bed in the DBs. This tends to reduce the net removal by the DB.

   iv. The use of sediment removal efficiencies to estimate metals removals in DBs will tend to over-estimate actual removal efficiencies for metals. It is expected that other metals will behave in a similar fashion, with the amount returned through bed desorption depending on the partition coefficient of the particular metal.

e. The degree of watershed impact depends on both the size of the watershed and the amount of drainage area tributary to, and controlled by, the DBs. In our studies, the changes in flow and load at the watershed outlet were relatively small because only 20% of the area was assumed to drain to the DBs. With larger fractions of the watershed draining to a DB, e.g. 30% to 50%, much greater changes on both flood peak and contaminant load reduction would be expected at the watershed outlet, and further downstream to the Bay. However, increasing the areas controlled will require larger DBs and more land, and thereby increasing costs, so that economic tradeoffs would need to be considered.

f. Locations of the DBs within the watershed will also affect the degree of flood peak and nonpoint load reduction. Our studies showed that locating the DBs to drain high nonpoint load sources (e.g. impervious areas) produces greater load reductions at the watershed outlet than if the DBs drained the same land use distribution as in the model segment. For flood reduction, locating the DBs in the upper watershed with the higher rainfall, steeper slopes, and greater runoff would likely have had a greater effect than uniformly locating the DBs throughout the watershed. Location decisions may require an analysis of tradeoffs between flood control and water quality, since the best location for flood control may not be the best for downstream water quality improvement. A watershed model like the one used in this study is an ideal tool for evaluating the potential impacts of DBs on flooding and water quality for alternative locations.

g. Although a limited number of scenarios were investigated in this study, the model can be used to investigate and evaluate the expected impact of alternative DB designs, e.g.

multiple ponds, alternative inflow/outflow structures, baffles/diversions, different operating procedures, vegetated banks and filtration areas, etc. Although ancillary benefits were not evaluated in this study, DBs with permanent pools can be designed and landscaped to provide for recreation and wildlife habitat, and can be integrated into, or provide the centerpiece, for local and/or regional parks.

Any model is only an approximation of reality; the models' utility depends on its' ability to provide a reasonable and sufficient representation of the key behavioral characteristics of the watershed so that it can be used as an effective tool to assess the likely impacts of alternative conditions. All models have limitations and there are limitations or assumptions in how they are applied in a given setting. Often an awareness of the model's assumptions and limitations is as important as the knowledge of its capabilities. HSPF has many limitations, but less than most watershed models. In this study, some key model and application limitations are evident. One model limitation is that copper is represented in only dissolved and sorbed phases, so that multiple dissolved species are not included. Application limitations include: (1) the model was calibrated to average daily storm peaks and EMCs, but not to storm hydrographs; and (2) the DBs were not site-specific designs, but generic refinements of a District design to represent detention impacts. Additional limitations and assumptions are noted in the description of HSPF (Section 2.2) and the DB simulations (Section 4.2.2).

### 1.3.2 RECOMMENDATIONS

Based on our watershed and DB modeling investigations, and our review of the literature, it is apparent that the District should consider the impacts of newly proposed and designed DBs on nonpoint loads and water quality. To this end we recommend the following procedures and conceptual criteria for all new facilities:

a. The potential impacts of the proposed DB design on nonpoint load reduction should be assessed, and credit should be given in terms of load reductions to the Bay. The amount of reduction will depend on both DB design and operating characteristics and pollutant characteristics. Removal efficiencies for metals should not be based on sediment removal as this will tend to over-estimate actual metal removal of a DB.

b. Alternative longer detention times, from 12 to 60 hours or more, should be assessed to determine the increased load reductions and water quality benefits that may accrue. Clearly, the longer times must also be evaluated in terms of negative impacts for flood control such as lesser reductions of peak flows.

c. The flood control and water quality impacts of proposed DBs need to be evaluated at both the local scale (i.e. at the outlet of the DB), and at the watershed scale. Impacts, such as changes in flood peaks and pollutant concentrations, may be small or negligible if less than 10% to 20% of the watershed is controlled by DBs. However, these impacts will be greater if additional DBs are approved and constructed within the watershed.

d. Since DBs are essentially 'treatment' options for reducing urban runoff pollutant loads, they should be evaluated in conjunction with 'source control' options that reduce the generation of nonpoint loads. Although source controls were not a focus of this study, our model simulations showed that water quality is very sensitive to local nonpoint loads. Comprehensive pollution control approaches, with both treatment and source control components, need to be evaluated at both the local and the watershed scale. The District should consider watershed modeling as a tool for this type of comprehensive pollution control and management.

The Calabazas Creek Watershed model provides a capability for investigating a wide range of additional scenarios and alternatives for both DB design and watershed-scale impacts. To help further refine the study conclusions and recommendations, the following should be considered by the District for further DB investigations :

a. Additional simulations should be performed with an increased area draining to the DBs, e.g. 30% to 50% of watershed area.

b. DBs with both shorter (e.g. 4 to 8 hours) and longer (e.g. 3 to 7 days) detention times should be modeled to refine the range of detention times where flood control is, or may be, seriously reduced in exchange for improved water quality.

c. Alternative locations of DBs should be investigated to explore the types of conflicts likely to develop between flood control and water quality improvement goals, and investigate possible compromises and solutions.

d. Additional DB designs should be simulated, e.g. multiple pools, off-channel storage, alternative inflow/outflow structures, etc. in order to explore a wider range of alternative DB configurations and operating procedures. These potential alternatives could help to achieve an more balanced tradeoff between acceptable levels of flood peak reduction and water quality improvement.

e. As noted above, since DBs are essentially treatment options for reducing urban runoff pollutant loads, they should be evaluated in conjunction with source controls options that reduce the generation of loads. A watershed model, like the Calabazas Creek Watershed model, can be used to analyze the tradeoffs between treatment and source control alternatives to help design a comprehensive watershed plan that includes an effective mix of both control approaches.

Although the HSPF application to the Calabazas Creek watershed showed reasonable calibration results and a good representation of the available observed data, further improvement is possible and is recommended. Recommendations for improving the model representation include the following:

a. Further calibration of the model with specific emphasis on individual storm events and peaks should be pursued to establish the ability to match short interval storm flood peaks. Lawn watering and point sources flows should be included in future simulations, and the long-term record used to generate the scenario results should be further investigated to insure a valid representation of meteorologic conditions throughout the watershed.

b. The model calibration and simulation period should be extended through 1996 to take advantage of the more recent and more reliable water quality data collected in the last few years.

c. Selected model parameters, such as the sediment settling velocities and bed exchange rates should be further investigated to establish their sensitivity and help further refine their calibrated values.

d. Additional pollutants should be modeled, such as alternative metals and nutrients, in order to include the capability to evaluate the influence of DBs on other metals of concern (e.g. nickel, lead, zinc) and nutrients (e.g. nitrogen and phosphorus forms).

e. Refined segmentation of the land uses, model segments, and channel segments would produce a more flexible and versatile model for examining channel behavior in greater detail, along with the impacts of alternative specific DB locations.

## 1.4 FORMAT OF THIS REPORT

In Section 2 we discuss the development of the overall methodology for the study, including the technical approach and watershed test site selection, along with an overview of the U.S. EPA HSPF model used in the study. Section 3 describes the HSPF model application to the Calabazas Creek Watershed including simulation and calibration results for hydrology, sediment, and water quality constituents. In Section 4, the detention basin scenario development, assumptions, and results are presented, and the study conclusions and recommendations are presented in Section 5.

# SECTION 2.0

# METHODOLOGY DEVELOPMENT

This section discusses the development of the procedures or methodology we used to evaluate the impacts of alternative detention scenarios on flood peaks, nonpoint pollution, and water quality. Below we discuss the overall technical approach based on the use of a comprehensive watershed model, we provide a brief description of the U.S. EPA HSPF model selected for use in this study, and we present the process we followed for selecting the Calabazas Creek Watershed as the test site for the study.

## 2.1 TECHNICAL APPROACH

Detention basins are often used in urban and developing areas to control the increased runoff and reduce the associated flooding from the increased imperviousness from urbanization. These basins function by providing sufficient storage to retain the inflow runoff and release it over a longer timeframe, thus allowing reduction of peak flows and associated flood levels and damage. Experience with detention basins has shown that they can also provide significant water quality benefits through pollutant settling, and that the degree of pollutant removal increases with the increased detention times (Grizzard et al., 1986). Unfortunately, with the increased detention time the effectiveness for flood peak reduction decreases because the storage available for flood control is decreased. Thus, we have the basic conflict between flood control and water quality improvement in detention basin analysis; the longer detention times needed for water quality improvement reduce the effectiveness of the basins for flood peak reduction by reducing the available storage volume for subsequent storms.

Loganathan et al (1994) have noted that detention basins designed for water quality need to capture the pollutant load, by providing sufficient storage volume, and then prevent the load from leaving through sufficient detention time. The 'storage volume' need is consistent with flood control needs, but the 'detention time' need is in direct conflict. The California Stormwater Quality Task Force (SQTF) (1993) described this conflict more in terms of the flood control need for 'peak shaving' storage of large design events, whereas the water quality control need is for storage (and retention) of initial runoff volumes, as shown conceptually in Figure 2.1 (CA SQTF, 1993). In many cases, the water quality control storage will retain the entire runoff for small events and the initial, or first-flush, pollutant load for larger events.

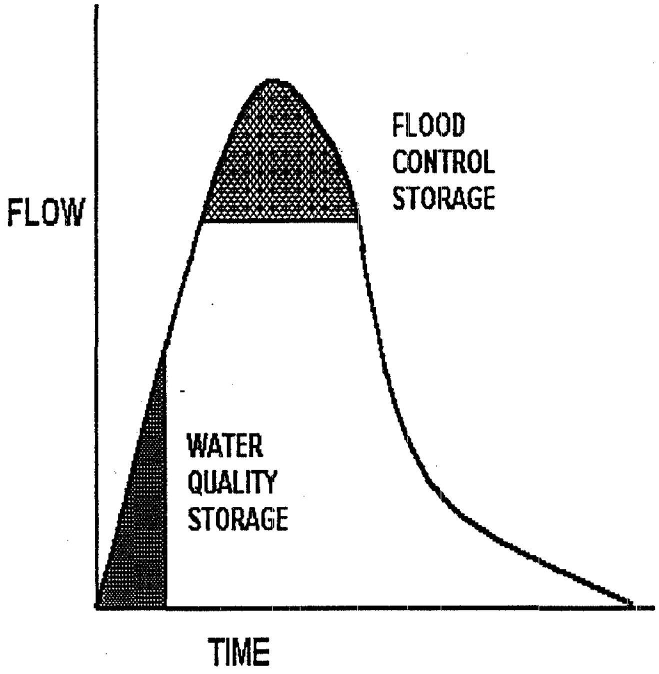

Figure 2.1 Storage Strategies for Flood Control and Water Quality Control

Pollutant removal efficiencies for detention basins vary widely for different types of ponds both as a function of local meteorologic and drainage area characteristics, and by pollutant characteristics. Debo and Reese (1995) appear to have prepared the most recent and most comprehensive review of detention basin (and other BMPs) effectiveness and removal efficiencies for various pollutants, and have tabulated removal values for a wide variety of types of detention facilities. The CA SQTF has compiled detailed design criteria for a variety of treatment control BMPs including various types of detention basins (CA SQTF, 1993). EPA, as part of their guidance under the 1990 Coastal Zone Act and Reauthorization Amendments (CZARA) (EPA, 1993a; EPA, 1993b) has published general guidance on pollutant removal efficiencies for selected types of detention basins (Table 2.1).

A number of studies have concluded that a continuous modeling approach is generally recommended for detention studies (Akan, 1992; Nix and Heaney, 1988; Akan et al., 1988; Sullivan and Schueler, 1985), even though current practices rely primarily on single-event analysis to size and design detention basins for specific sites. The sequence of storm events, which is especially important for flood control, cannot be captured by single-event analysis but is inherent in using a continuous watershed model. Even when alternative detention basin analysis methods are developed, they are often compared to model predictions for confirmation (Loganathan et al., 1994).

Table 2.1 EPA Guidance Document Removal Efficiencies for Detention Basins (EPA. 1993b)

| | | Removal Efficiency (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Management Practice** | | **TSS** | **TP** | **TN** | **COD** | **Pb** | **Zn** | **Factors** |
| EXTENDED DETENTION DRY POND | Average: | 45 | 25 | 30 | 20 | 50 | 20 | · Storage volume<br>· Detention time<br>· Pond shape |
| | Reported Range: | 5-90 | 10-55 | 20-60 | 0-40 | 25-65 | (-40)-65 | |
| | Probable Range: | 70-90 | 10-60 | 20-60 | 30-40 | 20-60 | 40-60 | |
| | No. Values Considered: | 6 | 6 | 4 | 5 | 4 | 5 | |
| WET POND | Average: | 60 | 45 | 35 | 40 | 75 | 60 | · Pool volume<br>· Pond shape |
| | Reported Range: | (-30)-91 | 10-85 | 5-85 | 5-90 | 10-95 | 10-95 | |
| | Probable Range: | 50-90 | 20-90 | 10-90 | 10-90 | 10-95 | 20-95 | |
| | No. Values Considered: | 18 | 18 | 9 | 7 | 13 | 13 | |
| EXTENDED DETENTION WET POND | Average: | 80 | 65 | 55 | NA | 40 | 20 | · Pool volume<br>· Pond shape<br>· Detention time |
| | Reported Range: | 50-100 | 50-80 | 55 | NA | 40 | 20 | |
| | Probable Range: | 50-95 | 50-90 | 10-90 | 10-90 | 10-95 | 20-95 | |
| | No. Values Considered: | 3 | 3 | 1 | 0 | 1 | 1 | |
| CONSTRUCTED STORMWATER WETLANDS | Average: | 65 | 25 | 20 | 50 | 65 | 35 | · Storage volume<br>· Detention time<br>· Pool shape<br>· Seasonal variation |
| | Reported Range: | (-20)-100 | (-120)-100 | (-15)-40 | 20-80 | 30-95 | (-30)-80 | |
| | Probable Range: | 50-90 | (-5)-80 | 0-40 | ---- | 30-95 | ---- | |
| | No. Values Considered: | 23 | 24 | 8 | 2 | 10 | 8 | |

A modeling approach was selected for this study because it provides the opportunity for the most comprehensive assessment of flood peak reduction and water quality. Furthermore, it allows direct evaluation of localized impacts of DBs and their downstream effects at the watershed outlet, which in this case would include loads to the Bay. In 1985, Sullivan and Schueler (1985) used an early version of the U.S. EPA HSPF model to evaluate impacts of various pond designs and types in the Washington, D.C. area, with the primary focus on pollutant removal. Figure 2.2 from their study includes diagrams of the three types of ponds they evaluated with HSPF -- conventional dry ponds, extended detention dry ponds, and wet ponds. The general approach developed by Sullivan and Schueler provided the initial concepts for the methodology developed and used in this study to extend the analysis to the joint assessment of DB effects on flood control and water quality.

The modeling approach and methodology developed for this study resulted in the following primary tasks:

1. Select the model as an assessment tool for this study
2. Identify a test watershed for model application
3. Develop the appropriate database for model application
4. Calibrate the model for the test watershed
5. Define the baseline conditions and alternative scenarios to assess
6. Define the model changes to represent baseline and scenarios
7. Run the model for baseline and scenarios
8. Analyze and compare model results
9. Prepare report and conclusions

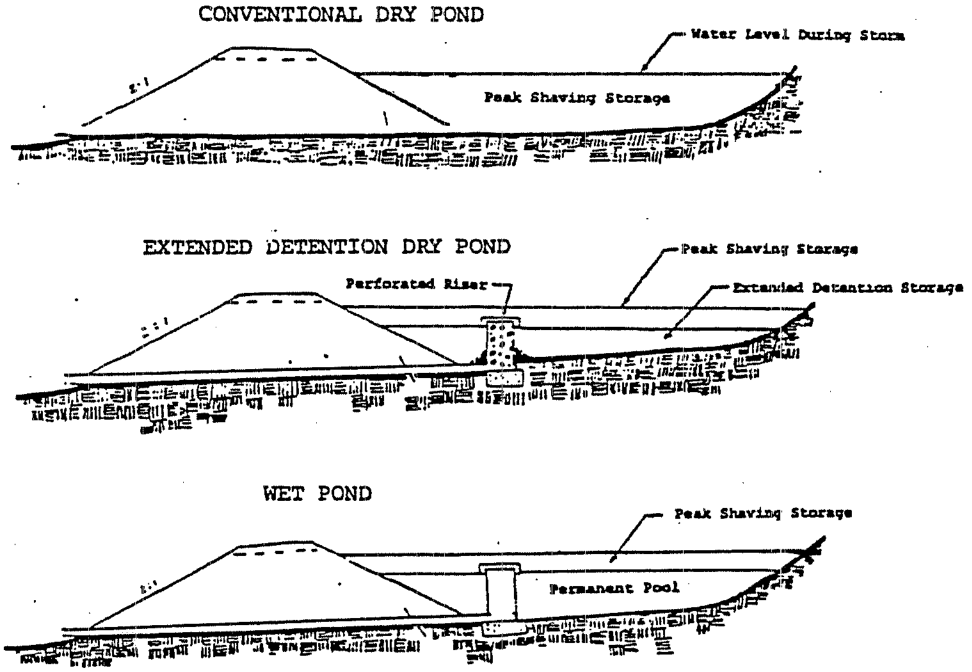

Figure 2.2 Alternative Types of Detention Ponds

### 2.1.1 EPA/NOAA Coastal Zone Nonpoint Pollution Program Requirements

In addition to the study tasks described above, the project scope of work included a review of the EPA Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 documents to identify any specific requirements related to detention basins. The EPA CZARA documents (EPA, 1993a; EPA, 1993b) were reviewed to determine to what extent the Federal nonpoint source requirements of CZARA might impact the assessment and design of detention basins by the District.

As part of CZARA, Congress enacted section 6217(g), entitled "Protecting Coastal Waters", requiring each coastal state with an approved Coastal Zone Management Program to develop a Coastal Nonpoint Pollution Control Program (CNPCP), and submit this program to the EPA and NOAA for review and approval by July 1995. EPA and NOAA were to complete their review process by January 1997, providing for an 18-month review period.

The EPA Guidance Document, entitled 'Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters' (EPA, 1993b) identifies management measures by five broad nonpoint source categories -- agriculture, silviculture, urban runoff, marinas, and hydromodifications. The guidance for urban runoff (including wetlands), includes extended duration dry ponds, extended duration wet ponds, and constructed wetlands in its list of potential management measures, along with some technical details such as expected ranges of removal efficiencies as shown in Table 2.1.

The State Water Resources Control Board is the designated lead agency for CZARA, and the program submitted to EPA/NOAA was developed through the joint efforts of the State Board and the Coastal Commission. These two agencies jointly submitted the program document (SWRCB/CCC, 1995) to EPA/NOAA in September 1995.

According to the Santa Clara Valley Nonpoint Source Pollution Control Programs's Stormwater Management Plan (SWMP) (SCVNSPCP, 1994), the programs submitted under CZARA must adopt management measures consistent with the EPA Guidance document, and these measures must be fully implemented by January 1999. Management measures required under NPDES permits to control pollutants to the "Maximum Extent Practicable" would likely qualify under CZARA, as the EPA guidance is not all inclusive. Furthermore, the SWMP indicates there are some questions regarding the jurisdiction of CZARA, and its relation to existing NPDES permits. However, the EPA Guidance clearly states that "CNPCP ... and the management measures they contain, apply only to sources that are not required under EPA's regulations to obtain an NPDES permit" (EPA, 1993b, pg 1-10). Direction to the District from the Regional Board is that the program must implement the urban runoff, wetlands, and hydromodification measures (SCVWD, 1994).

As of mid-February 1997, the EPA and NOAA have responded to the CNPCP document with a draft letter of findings that are currently being further reviewed and discussed among state and federal officials. A Draft Notice of findings and recommendations is expected to be published in the Federal Register within the next 30 - 45 days, at which time public review will be requested. Discussions with SWRCB staff indicate that, at this time, no new mandates or requirements are expected to be imposed upon local agencies (J. Ladd, Personal communication, 1997).

In the remaining sections of this chapter, a short overview of the U.S. EPA HSPF model is presented, and the test watershed site selection process is described. Those readers not interested in the HSPF model, or already familiar with it, can skip Section 2.2 and go directly to Section 2.3. In Section 3, we describe the HSPF model application to Calabazas Creek along with the database development i.e. tasks 3 and 4 above, and discuss the calibration results. The scenario development and simulation results are presented in Section 4, while Section 5 summarizes the study conclusions and recommendations.

## 2.2 U.S. EPA HSPF MODEL DESCRIPTION

In the mid-1970's, the U.S. EPA Environmental Research Laboratory in Athens, Georgia was in the beginning stages of model development and testing efforts that focused on tools and procedures for quantifying nonpoint sources (NPS) of pollution. Initiated by legislative mandates that required assessment of both urban and agricultural NPS contaminants, the Laboratory was supporting development and field testing of mathematical models (along with companion data collection programs) to be used to estimate these NPS loadings and, ultimately, to evaluate potential management and control alternatives. However, EPA scientists realized that although these field-scale models could provide loading values, they alone would not be sufficient to evaluate water quality impacts at the larger watershed, or regional scale. Thus began an extensive, comprehensive watershed model development effort to integrate the field-scale models with instream hydraulic and water quality process models, within a flexible, modular framework, to allow continuous simulation of complex watersheds with multiple land uses, both point and nonpoint contaminant sources, networked channels and drainage patterns, and lakes and reservoirs. The HSPF model produced by this development effort has been applied throughout North America and numerous countries and climatic regimes around the world; it enjoys the joint sponsorship of both the U.S. Environmental Protection Agency and the U.S. Geological Survey, and continues to undergo refinement and enhancement of its component simulation capabilities along with user support and code maintenance activities.

### 2.2.1 Overview

The Hydrological Simulation Program-FORTRAN, known as HSPF, is a mathematical model developed under EPA sponsorship for use on digital computers to simulate hydrologic and water quality processes in natural and man-made water systems. It is an analytical tool which has application in the planning, design, and operation of water resources systems. The model enables the use of probabilistic analysis in the fields of hydrology and water quality management. HSPF uses such information as the time history of rainfall, temperature, evaporation, and parameters related to land use patterns, soil characteristics, and agricultural practices to simulate the processes that occur in a watershed. The initial result of an HSPF simulation is a time history of the quantity and quality of water transported over the land surface and through various soil zones down to the groundwater aquifers. Runoff flow rate, sediment loads, nutrients, pesticides, toxic chemicals, and other quality constituent concentrations can be predicted. The model uses these results and stream channel information to simulate instream processes. From this information, HSPF produces a time history of water quantity and quality at any point in the watershed.

HSPF is currently one of the most comprehensive and flexible models of watershed hydrology and water quality available. It is the only available model that can simulate the continuous, dynamic event, or steady-state behavior of both hydrologic/hydraulic and water quality processes in a watershed, with an integrated linkage of surface, soil, and stream processes. The model is also unusual in its ability to represent the hydrologic regimes of a wide variety of streams and rivers with reasonable accuracy. It has been applied to such diverse climatic regimes as the tropical rain forests of the Caribbean, arid conditions of Saudi Arabia and the Southwestern U.S., the humid Eastern U.S. and Europe, and snow covered regions of Eastern Canada. The potential applications and uses of the model are comparatively large including:

- Flood control planning and operations
- Hydropower studies
- River basin and watershed planning
- Storm drainage analyses
- Water quality planning and management
- Point and nonpoint source pollution analyses
- Soil erosion and sediment transport studies
- Evaluation of urban and agricultural best management practices
- Fate, transport, exposure assessment, and control of pesticides, nutrients, and toxic substances
- Time-series data storage, analysis, and display

HSPF is designed so that it can be applied to most watersheds using existing meteorologic and hydrologic data; soils and topographic information; and land use, drainage, and system (physical and man-made) characteristics. The inputs required by HSPF are not different than those needed by most other simpler models. The primary difference in data needs is that long, rather than short time-series records are preferred. Typical long time-series records include precipitation, waste discharges, and calibration data such as streamflow and constituent concentrations.

### 2.2.2 Historical Development

HSPF is an extension and improvement of three previously developed models: 1) The EPA Agricultural Runoff Management Model - ARM (Donigian and Davis, 1978), 2) The EPA Nonpoint Source Runoff Model - NPS (Donigian and Crawford, 1979), and 3) The Hydrologic Simulation Program (HSP), including HSP Quality (Hydrocomp, 1977), a privately-developed proprietary program. In the late 70's EPA recognized that the continuous simulation approach contained in these models would be valuable in solving many complex water resource problems. Thus, a fairly large investment was devoted to developing a highly flexible non-proprietary FORTRAN program which contains the capabilities of these three models, plus many extensions.

HSPF was first released publicly in 1980, as Release No. 5 (Johanson et al., 1980), by the U.S. EPA Water Quality Modeling Center (now the Center for Exposure Assessment Modeling); since its initial release, the model has maintained a reputation as perhaps the most useful watershed-scale hydrology/water quality model that is available within the public domain. The development of HSPF in the late 1970's represented an integration of a variety of EPA-sponsored model development and testing efforts. The basic watershed modeling philosophy and approach embodied in HSP was chosen, a highly modular code design and structure was developed, and all the individual models were redesigned and recoded into FORTRAN to make the resulting package widely useable and available to potential model users. Throughout the 1980's and early 1990's, HSPF underwent a series of code and algorithm enhancements producing a continuing succession of new releases of the code, culminating in the recent release of Version No. 11 in 1996 (Bicknell et al., 1996). Table 2.2 lists some of the key enhancements and changes for the various HSPF releases since 1980.

Since 1981, the U.S. Geological Survey has been developing software tools to facilitate watershed modeling by providing interactive capabilities for model input development, data storage and data analysis, and model output analysis including hydrologic calibration assistance. The ANNIE, WDM, Scenario Generator, and HSPEXP software are USGS products that have greatly advanced and facilitated watershed model applications, not only for HSPF but also for many other USGS models. For example, the WDM (Watershed Data Management) file has effectively replaced the Time Series Store (TSS) file used in the earlier versions of HSPF due to the expanded data analysis and graphical capabilities of the ANNIE software (Lumb et al., 1990).

HSPF applications since its initial release in 1980 have been world-wide and number in the hundreds; on the order of 50 current active applications continue around the world with the greatest concentration in North America. Numerous studies have been completed or are continuing in the Pacific Northwest, Washington, D.C. metropolitan area, and the Chesapeake Bay region; Table 2.3 lists a few current HSPF applications discussed by Donigian et al (1995). Today the model serves as the focal point for cooperation and integration of watershed modeling and model support efforts between the Environmental Protection Agency and the U.S. Geological Survey. Over the years, development activities and model enhancements, along with these model applications, have continued to improve the model's capabilities and preserve its status as a state-of-the-art tool for watershed analysis. Our purpose in this section is neither to duplicate nor to summarize the materials available in the HSPF User Manual (Bicknell et al., 1996). Interested readers and potential users are referred to the HSPF User Manual for complete details of the model algorithms. Rather, our goals are to provide an overview of the model capabilities, with specific reference to those model sections used to model the Calabazas Creek Watershed.

**Table 2.2 Historical Progression of HSPF Releases**

| Year | Version | Comments/Enhancements | Document |
|---|---|---|---|
| 1980 | 5<br>6 | Initial public release<br>Performance and portability enhancements | Johanson et al. (1980) |
| 1981 | 7 | GQUAL, SEDTRN, MUTSIN, GENER, DURANL enhancements | Johanson et al. (1981) |
| 1984 | 8 | Special Actions enhancements<br>Initial PC version | Johanson et al. (1984)<br>Application Guide (Donigian et al., 1984) |
| 1988 | 9 | WDM implementation<br>PC version distributed | CEAM publication |
| 1993 | 10 | Sediment-nutrient interactions<br>Mass-Link/Schematic<br>Acid-pH Module | HSPF Rel. 10 Manual<br>Bicknell et al., 1993) |
| 1996 | 11 | Enhanced special actions<br>Water regulation/accounting<br>Atmospheric deposition<br>HSPF/DSS linkage (COE)<br>Increased operations limit<br>Forest Nitrogen Module | HSPF Rel. 11 Manual<br>(Bicknell et al., 1996) |

### 2.2.3 Overview of HSPF Capabilities and Components

HSPF contains three application modules and five utility modules. The three application modules simulate the hydrologic/hydraulic and water quality components of the watershed. The utility modules are used to manipulate and analyze time-series data. Table 2.4 summarizes the constituents and capabilities of the HSPF modules. A brief description of each of the modules follows.

The three application modules within HSPF, and their primary functions, are as follows:

(1) PERLND - Simulates runoff and water quality constituents from pervious land areas in the watershed.

**Table 2.3 Selected Recent and/or Current HSPF Applications**

- Chesapeake Bay Watershed Model of nutrient loadings and management alternatives
- Seattle Metropolitan Area watershed and urban drainage studies
- Metropolitan Washington, DC urban nonpoint and water quality studies
- U.S. EPA Office of Pesticide Programs assessment of alachlor surface water concentrations
- Sydney Water Board (Australia) assessment of water supply quality and nonpoint pollution
- Maryland Department of the Environment Patuxent River nonpoint source study
- Numerous Florida applications for hydrologic assessments, nutrient loadings and water quality simulation
- Flooding and Water Resource Development studies for Saudi Arabian Ministry of Agriculture
- Upper Grande Ronde (OR) temperature TMDL
- Walnut Creek (IA) MSEA/MASTER surface water exposure assessment
- Minnesota River Nonpoint Source Assessment Project
- Water Management for the Humber River, South Africa
- Connecticut Nutrient Management Plan for Long Island Sound

(2) IMPLND - Simulates impervious land area runoff and water quality.

(3) RCHRES - Simulates the movement of runoff water and its associated water quality constituents in stream channels and mixed reservoirs.

### 2.2.4 PERLND Module

As PERLND simulates the water quality and quantity processes that occur on pervious land areas, it is the most frequently used part of HSPF. To simulate these processes, PERLND models the movement of water along three paths: overland flow, interflow, and groundwater flow. Each of these three paths experiences differences in time delay and differences in interactions between water and its various dissolved constituents. A variety of storage zones are used to represent the processes which occur on the land surface and in the soil horizons.

Snow accumulation and melt are also included in the PERLND module so that the complete range of physical processes affecting the generation of water and associated water quality constituents can be represented. Some of the many capabilities available in the PERLND module include the simulation of:

- water budget and runoff components
- snow accumulation and melt
- sediment production and removal

**Table 2.4 HSPF Application and Utility Modules**

## Application Modules

| PERLND | IMPLND | RCHRES |
|---|---|---|
| Snow | Snow | Hydraulics |
| Water | Water | Conservative |
| Sediment | Solids | Temperature |
| Soil temperature | Quality | Sediment |
| Quality | | Nonconservatives |
| Pesticide | | BOD/DO |
| Nitrogen | | Nitrogen |
| Phosphorus | | Phosphorus |
| Tracer | | Carbon/pH |
| | | Plankton |

## Utility Modules

| COPY | PLTGEN | DISPLY |
|---|---|---|
| Data transfer | Plot data | Tabulate, summarize |
| DURANL | GENER | MUTSIN |
| Duration Analysis | Transform or combine time series data | Input sequential time series data |

- accumulation and washoff of user-defined nonpoint pollutants
- nitrogen and phosphorus fate and runoff
- pesticide fate and runoff
- movement of a tracer chemical

The PERLND module features individual compartments (i.e. subroutine groups) for specific modeling capabilities, including : air temperature as a function of elevation (ATEMP), snow accumulation and melting (SNOW), hydrologic water budget (PWATER), sediment production and removal (SEDMNT), soil temperature (PSTEMP), surface runoff water temperature and gas concentrations (PWTGAS), generalized water quality constituents (PQUAL), solute transport (MSTLAY), pesticides (PEST), nitrogen (NITR), phosphorus

(PHOS), and conservatives (TRACER). For the Calabazas Study, only the PWATER, SEDMNT, PWTGAS, and PQUAL capabilities were required; these are discussed briefly below.

PWATER is used to calculate the water budget components resulting from precipitation on pervious land areas; as a result, it is the key component of the PERLND module. The basis of the water budget computations contained in HSPF is the Stanford Watershed Model (Crawford and Linsley, 1966). Like the SNOW code, the PWATER code uses both physical and empirical formulations to model the movement of water through the hydrologic cycle. PWATER considers such processes as evapotranspiration; surface detention; surface runoff; infiltration; shallow subsurface flow (interflow); baseflow; and percolation to deep groundwater. Lateral inflows to surface and shallow subsurface storages can also be modeled.

The equations used in the SEDMNT code to produce and remove sediment are based on the ARM and NPS models, and are modifications of soil and gully erosion equations developed by Negev (1967) and influenced by Meyer and Wischmeier (1969) and Onstad and Foster (1975). Many of the sediment model parameters are derived from the Universal Soil Loss Equation (Wischmeier and Smith, 1978). Removal of sediment by water is simulated as washoff of detached sediment in storage and scour of the soil matrix. Soil detachment is modeled as a function of rainfall, land cover, land management practices, and soil detachment properties. If the modeler so specifies, soil detachment can be incremented by lateral input from an upslope land segment and/or net external additions/removals caused by human activities or wind. Removal of detached sediment and scour of the soil matrix by surface flow are both modeled empirically as a function of surface water storage and surface water outflow.

PWTGAS estimates the water temperature for surface, shallow subsurface (interflow) and groundwater outflows. The temperature of each outflow is considered to be the same as the soil temperature of the layer from which it originates. PWTGAS also computes the dissolved oxygen and carbon dioxide concentrations of overland flow using empirical formulations; concentrations are assumed to be at saturation.

PQUAL simulates generalized water quality constituents in the outflows (surface and subsurface) from a pervious land segment using simple relationships with water and/or sediment yield. The behavior of a constituent in surface outflow is considered more complex and dynamic than the behavior in subsurface flow. The code allows quantities in surface outflow to be simulated by one, or both, of two methods. Either (1) a constituent can be modeled using "potency factors" to indicate constituent strength relative to the sediment removal computed by SEDMNT, or (2) storage of a constituent on the land surface can be modeled, considering accumulation and depletion/removal, and a first-order washoff rate of the available constituent can be removed by overland flow, as computed by PWATER. In addition, both formulations can be used for representing the washoff behavior of particulate and dissolved components of an specific pollutant.

The remaining five code compartments in PERLND are used together to model detailed behavior of soil nutrients (i.e. nitrogen and phosphorus) and non-reactive tracer chemicals (e.g. chloride). These five code sections have been referred to as the AGCHEM module because their primary use to date has been for modeling the mass balance and runoff of agricultural chemicals. These sections were not used in the Calabazas Study, so interested readers are referred to the User Manual and Donigian et al (1995) for details.

### 2.2.5 IMPLND Module

IMPLND is used for impervious land surfaces, primarily for urban land categories, where little or no infiltration occurs. However, some land processes do occur, and water, solids, and various pollutants are removed from the land surface by moving laterally downslope to a pervious area, stream channel, or reservoir. IMPLND includes most of the pollutant washoff capabilities of the commonly used urban runoff models, such as the STORM, SWMM, and NPS models.

The IMPLND module shares much of its code with PERLND, but is simplified since infiltration and other interactions with the subsurface cannot occur. The module features individual compartments for modeling air temperature as a function of elevation (ATEMP), snow accumulation and melting (SNOW), hydrologic water budget (IWATER), solids accumulation and removal (SOLIDS), surface runoff water temperature and gas concentrations (IWTGAS), and generalized water quality constituents (IQUAL).

One difference between PERLND and IMPLND process representation is of note. In the SOLIDS code section, IMPLND offers the capability to model the accumulation and removal of urban solids (i.e. solids on impervious areas) by processes which are independent of storm events (e.g., street cleaning, decay, wind deposition or scour). To use this option, the modeler needs to assign monthly or constant rates of solids accumulation and removal, estimate parameter values for impervious solids washoff (analogous to methods in the SEDMNT module of PERLND), and provide 'potency factor' values for constituents associated with the solids removed. Alternatively, the IQUAL module can be used to represent accumulation and removal processes for each constituent individually, analogous to the PQUAL approach.

### 2.2.6 RCHRES Module

RCHRES is used to route runoff and water quality constituents simulated by PERLND and IMPLND through stream channel networks and reservoirs. The module simulates the processes that occur in a series of open or closed channel reaches or a completely mixed lake. Flow is modeled as unidirectional. A number of processes can be modeled, including:

- hydraulic behavior
- heat balance processes that determine water temperature
- inorganic sediment deposition, scour, and transport by particle size

- chemical partitioning, hydrolysis, volatilization, oxidation, biodegradation, and generalized first-order (e.g. radionuclides) decay, parent chemical/metabolite transformations
- DO and BOD balances
- inorganic nitrogen and phosphorous balances
- plankton populations
- pH, carbon dioxide, total inorganic carbon, and alkalinity

The RCHRES module features individual compartments for modeling hydraulics (HYDR), constituent advection (ADCALC), conservatives (CONS), water temperature (HTRCH), inorganic sediment (SEDTRN), generalized quality constituents (GQUAL), specific constituents involved in biochemical transformations (RQUAL), and acid mine drainage phenomena (ACIDPH).

HYDR simulates the processes that occur in a single reach of an open channel or a completely mixed lake. Hydraulic behavior is modeled using the kinematic wave assumption. All inflows to a reach are assumed to enter at a single upstream point. The outflow of a reach may be distributed across several targets that might represent normal outflows, diversions, and multiple gates of a reservoir. In HSPF, outflows can be represented by either, or both, of two methods:

(1) Outflow can be modeled as a function of reach volume for situations where there is no control of flows or gate settings are only a function of water level.

(2) Outflow can be modeled as a function of time to represent demands for municipal, industrial, or agricultural use. To do so, the modeler must provide a time series of outflow values for the outflow target that is time-dependent and independent of reach volume.

If an outflow demand has both volume-dependent and time-dependent components, the modeler can, and must, specify how the components are combined to define the resulting outflow demand. HSPF allows the modeler to define the resulting demand in one of three manners: (1) as the minimum of the two components, (2) as the maximum of the two components, or (3) as the sum of the two components.

HSPF makes no assumptions regarding the shape of a reach; however, the following assumptions are made:

(1) There is a fixed, user-defined, relation between water depth, surface area, volume, and discharge. This is specified in a Function Table (or FTABLE) defined for each reach by the user.

(2) For any outflow demand with a volume-dependent component, the relation between the above variables is usually constant in time; however, pre-determined seasonal or daily variations in discharge values can be represented by the user.

These assumptions rule out cases where flow reverses directions (e.g. estuaries) or where one stream reach influences another upstream of it in a time-dependent way. Momentum is not considered, and the routing technique falls in the class known as "storage routing" or "kinematic wave" methods.

In addition to calculating outflow rates and reach water volumes, HYDR computes the values for additional hydraulic parameters that are used in the other code sections of RCHRES including depth, stage, surface area, average depth, top width, hydraulic radius, bed shear stress and shear velocity.

The approach taken by the SEDTRN code compartment to compute transport of channel sediment is based on the SERATRA model developed by Battelle Laboratories (Onishi and Wise, 1979). Both noncohesive (sand) and cohesive (silt, clay) sediments are simulated in SEDTRN; migration of each sediment fraction between suspension in water and the bed is modeled by balancing deposition and scour computations. The code allows the modeler to compute the deposition or scour of noncohesive sediment by selecting one of three empirical formulations:

(1) A user-defined power function of streamflow velocity,

(2) A relationship (Toffaleti method) dependent upon median sand particle diameter, average stream velocity, reach hydraulic radius, reach slope, settling velocity for sand (user-specified), and water temperature,or

(3) A relationship (Colby method) dependent upon median sand particle diameter, average stream velocity, reach hydraulic radius, fine sediment load concentration, and water temperature.

The simulation of cohesive sediment transport consists of two steps. First, advective transport is calculated; then deposition and scour is calculated based on the calculated bed shear stress. To evaluate deposition, the modeler is required to provide values for settling velocity and critical shear stress for deposition for each fraction (silt, clay) of cohesive sediment that is modeled. To evaluate resuspension, or scour, the modeler must provide values for the erodibility coefficient and critical shear stress for scour for each fraction.

The focus of the GQUAL code development was to allow simulation of agricultural pesticides and other synthetic organic chemicals. Given the diversity of pesticides that might be modeled, the code provides the user with the capability to model any subset of the following generalized processes: advection of dissolved material; decay of dissolved material by hydrolysis, oxidation by free radical oxygen, photolysis, volatilization, biodegradation, and/or generalized first-order decay; production of one modeled constituent as a result of decay of another constituent; advection of adsorbed suspended material; deposition and scour of adsorbed material; and adsorption/desorption between dissolved and sediment-associated phases. Using the GQUAL section in conjunction with the sediment transport code (SEDTRN), adsorbed chemicals may settle or resuspend during each simulation time step, depending on hydrodynamic conditions. Decomposition of adsorbed chemicals may be simulated, both in suspended materials and in the bed, by using a first-order, temperature-corrected decay formulation.

The RQUAL code provides detailed simulation of constituents involved in biochemical transformations. Included are dissolved oxygen, BOD, ammonia, nitrite, nitrate, phosphate, phytoplankton, benthic algae, zooplankton, refractory organics, and pH. The primary dissolved oxygen and biochemical oxygen demand balances are simulated with provisions for decay, settling, benthal sinks and sources, reaeration, and sinks and sources related to plankton. The primary nitrogen balance is modeled as sequential reactions from ammonia through nitrate. Ammonia volatilization, ammonification, denitrification, and ammonium adsorption/desorption interactions with suspended sediment fractions are also considered. Both ammonium and phosphate adsorption/desorption to suspended sediment fractions are modeled using an equilibrium, linear isotherm approach. Both nitrogen and phosphorus species are considered in modeling three types of plankton - phytoplankton, attached algae and zooplankton. Phytoplankton processes that are modeled include growth, respiration, sinking, zooplankton predation, and death; zooplankton processes include growth, respiration and death; and benthic algae processes modeled are growth, respiration and death. Hydrogen ion activity (pH) can be calculated by two independent code sections. The first, named PHCARB, is contained within the RQUAL section and computes pH by considering carbon dioxide, total organic carbon and alkalinity. In doing so, the code considers the effects on the carbon dioxide-bicarbonate system of carbon dioxide invasion, zooplankton respiration, BOD decay, net growth of algae, and benthal releases.

## 2.3 TEST SITE SELECTION

Discussions with District personnel and the information included in the Santa Clara Valley Nonpoint Source Study Loads Assessment Report (WCC, 1991) indicated a reasonable database for a watershed model demonstration application to one of the 11 watersheds draining the Santa Clara Valley. The test watershed selection was made in conjunction with District staff to choose a site that included both land use and instream monitoring stations, along with a sufficient period of record of concurrent precipitation, streamflow data, and water quality data. Up to 20 years of data was available at selected sites that also include limited data for water quality.

Table 2.5 lists the comparative advantages and disadvantages of the three potential watershed sites identified jointly with District staff - Calabazas Creek, Sunnyvale East Channel, and Ross Creek. The information used to develop the advantages and disadvantages includes the WCC Loads Assessment Report (WCC, 1991a; WCC, 1991b), Mangarella (1993), monitoring information provided by District staff, and personal communications with District NPS staff (D. Drury) and WCC (P. Mangarella). These personal communications indicated that water quality data collection has been continuing at a selected number of sites since the Loads Report was published (1991), including both Calabazas Creek and Sunnyvale East Channel.

Based on the information in Table 2.5, we recommended selection of either Calabazas Creek or Sunnyvale East Channel, with the higher priority to Calabazas Creek. Both sites appeared to have adequate flow and water quality data for an HSPF application, and the rainfall gage distribution appeared to be adequate for both sites. Calabazas Creek has both upstream and outlet flow sites, and it includes a wider range of land use, topographic, and climatic variation that better represents the range of conditions within the District. Final site selection of Calabazas Creek was made jointly with District staff so that any other considerations or issues could be identified and discussed.

## Table 2.5 Comparative Advantages and Disadvantages of Three Potential Test Sites

| POTENTIAL SITE | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| Calabazas Creek | Two flow gages (#31, #36a)<br>Water quality data at outlet<br>Mostly natural channels<br>Relatively wide precip range (13"-32")<br>Includes both upland and valley topography<br>Both Open (20%) and Resid/Comm (80%) land<br>Multiple recording rain gages nearby<br>No reservoirs<br>Site of WCC SWMM application | No land use sampling sites<br>Largest of 3 potential sites |
| Sunnyvale East Channel | Two land use sampling sites within watershed<br>Water quality data at outlet<br>Site of WCC detention study<br>No reservoirs | Only 1 flow gage (#74)<br>Mostly all channelized<br>Narrow precip range (12"-16")<br>All urbanized: Resid (68%), Comm (32%)<br>Mostly flat valley topography |
| Ross Creek | Two flow gages (#21, #51)<br>Multiple recording rain gages nearby<br>Both Open (24%) and Resid/Comm (73%)land<br>Site of District detailed urban hydrology study<br>No reservoirs | No water quality data<br>No land use sampling sites |

# SECTION 3.0

# HSPF MODEL APPLICATION TO CALABAZAS CREEK

As part of the Study Approach, the HSPF model (Bicknell et al., 1993; 1996) was applied to Calabazas Creek in order to evaluate the effects of alternative detention basin scenarios on NPS runoff and water quality. This section describes the data and application procedures used, and the modeling results obtained in applying HSPF to Calabazas Creek. Model application followed the standard approach described by Donigian et al (1984) including the database development, watershed segmentation, hydrology calibration and verification, and sediment and water quality calibration. The following sections describe each of these efforts, along with the model results, as a basis for the simulation of alternative scenarios discussed in Section 4.0.

## 3.1 DATABASE DEVELOPMENT

The precipitation, evaporation, streamflow, and watershed data for the study were provided by the Hydrology and Basic Data sections of the District. All the timeseries information was placed in an electronic database in the form of a Watershed Data Management (WDM) file (Lumb and Kittle, 1987; Lumb et al., 1990). This binary format file and modeling database system was developed for the USGS for flexibility, compactness and speed of retrieval, and to allow a single database to be used for a variety of hydrologic and hydraulic models, including HSPF. All timeseries data received from the District were reformatted into this file. The same file is used to store all the model input timeseries and the results of the runs. Data pre-processing and post-processing was done primarily using the WDM utility program ANNIE (Flynn et al., 1994).

Precipitation data was provided by the District for nine selected stations located in and around the Calabazas Creek watershed (See Figure 3.1). Six of these stations were chosen as primary stations based on their location, and a network of Thiessen polygons was overlaid on the subbasin boundaries; Tables 3.1 and 3.2, respectively, identify the stations and list the annual values for the 20-year period. Missing values for each of the six chosen stations were estimated using an average of values from adjacent primary and secondary stations. An hourly time step was selected for the simulation, so fifteen-minute data sets were aggregated and daily stations were disaggregated to hourly values. These steps were accomplished using the USGS data utility program METCMP (Lumb and Kittle, 1995).

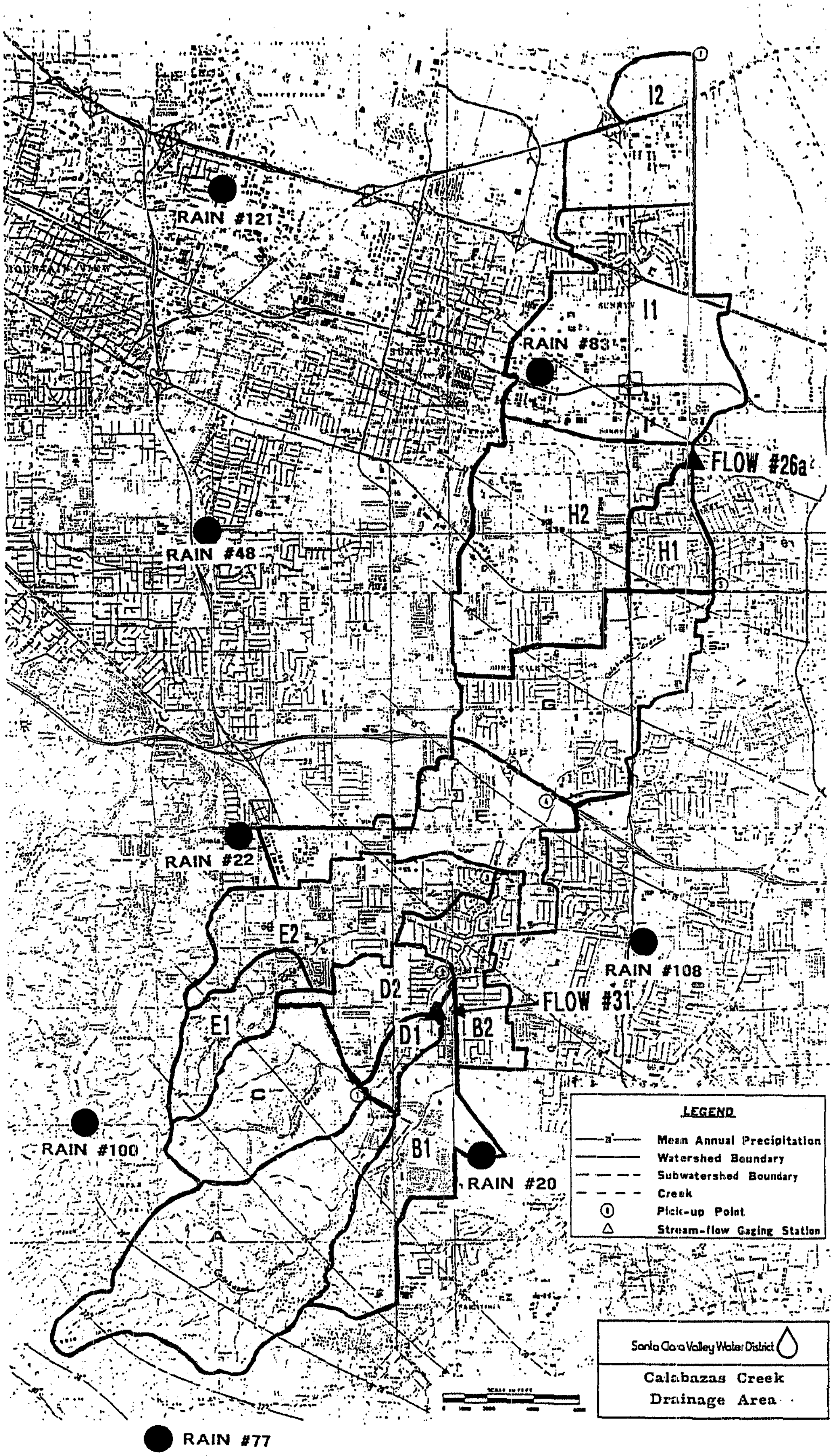

Figure 3.1 Calabazas Creek Watershed Map and Segmentation

## Table 3.1 Precipitation Stations for the Calabazas Watershed - July 1972 to June 1992

| SCVWD ID | Interval | Approximate Location |
|---|---|---|
| Primary Stations | | |
| 20 | Daily | Prospect & Hwy 85 |
| 22 | Daily | Stelling & Stevens Creek Blvd |
| 77 | 15 Min | Upper Saratoga Creek |
| 83 | Daily | Central & Sunnyvale East |
| 100 | 15 Min | Stevens Creek Reservoir |
| 108 | 15 Min | Lawrence Expy & Stevens Creek Blvd |
| Secondary Stations (used for filling and disaggregation) | | |
| 48 | 15 Min | Stevens Creek & Permanente Diversion |
| 86 | Hourly | Monterey & Taylor |
| 121 | 15 Min | Hwy 101 & Stevens Creek |

## Table 3.2 Precipitation Data for Selected Gages - Annual Totals

| | Station | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | 20 | 22 | 48 | 77 | 83 | 86 | 100 | 108 | 121 |
| 1973 | 33.15 | 27.95 | - | 59.50 | 25.41 | 24.10 | 36.39[a] | 18.34[a] | - |
| 1974 | 23.76 | 21.02 | - | 49.80 | 16.76 | 19.25 | 29.24[a] | 19.40 | - |
| 1975 | 22.54 | 17.51 | - | 40.00 | 13.78 | 19.25 | 29.40 | 15.60 | - |
| 1976 | 7.45 | 6.92 | 6.20 | 15.70 | 5.98 | 5.77 | 10.50 | 6.00 | 5.00 |
| 1977 | 9.41 | 9.32 | 8.80 | 19.20 | 8.32 | 8.98 | 14.40 | 7.70 | 8.80 |
| 1978 | 35.81 | 27.23 | 24.80 | 69.20 | 19.66 | 22.07 | 43.00 | 24.20 | 19.90 |
| 1979 | 17.28 | 15.33 | 13.10 | 40.60 | 10.97 | 12.17 | 25.80 | 12.40 | 11.60 |
| 1980 | 30.99 | 24.39 | 21.70 | 61.00 | 17.17 | 18.78 | 39.50 | 20.80 | 17.00 |
| 1981 | 15.19 | 12.58 | 11.20 | 31.80 | 10.22 | 10.96 | 20.20 | 11.20 | 9.60 |
| 1982 | 32.98 | 26.81 | 25.00 | 75.10 | 21.27 | 21.94 | 46.70 | 22.80 | 22.30 |
| 1983 | 39.47[a] | 39.99 | 34.10 | 96.70 | 30.50 | 30.33 | 62.10 | 32.50 | 30.00 |
| 1984 | 20.33 | 16.04 | 12.90 | 41.30 | 10.22 | 13.44 | 24.70 | 13.50 | 12.10 |
| 1985 | 13.94 | 15.72 | 12.90 | 36.20 | 11.91 | 12.63 | 21.70 | 11.00 | 12.70 |
| 1986 | 30.81 | 32.32 | 22.10 | 68.40 | 11.45 | 17.74 | 29.80 | 21.20 | 19.60 |
| 1987 | 11.37 | 10.06 | 7.90 | 23.70 | 7.52 | 7.79 | 13.20 | 7.60 | 7.50 |
| 1988 | 13.44 | 11.28 | 8.30 | 28.10 | 10.49 | 11.11 | 17.30 | 8.70 | 9.00 |
| 1989 | 10.21 | 8.65 | 6.90 | 29.40 | 9.39 | 8.23 | 13.60 | 4.50 | 7.40 |
| 1990 | 9.98 | 10.96 | 9.20 | 30.30 | 8.28[a] | 10.38 | 17.20 | 9.00 | 9.00 |
| 1991 | 15.14 | 13.54 | 11.70 | 37.50 | 10.32[a] | 11.87 | 22.40 | 11.20 | 11.00 |
| 1992 | 21.62[a] | 19.41[a] | 16.70 | 42.20 | 13.77[a] | - | 30.60 | 14.70 | 13.70 |
| Ave Annual Total | 20.74 | 18.35 | 14.91 | 44.79 | 13.67 | 15.09 | 27.39 | 14.62 | 13.31 |

[a] Includes estimated data

Monthly evaporation data and pan factors were supplied by the District from the Los Alamitos Recharge Facility Class A evaporation pan. Daily evaporation data is generally preferred for continuous hydrologic simulation, but the use of monthly data is considered acceptable for this study with its focus on storm flows within a semi-arid hydrologic regime. Data from a local DWR evaporation site (U.C. Bay Area Research and Extension Center, Santa Clara) was investigated, but their monthly values were not significantly different, and were not used. The District data is shown in Table 3.3, with the monthly values calculated from the monthly pan factors and the original monthly pan evaporation.

Observed streamflow data are available at two sites on the creek. District Gage 31 is in the upper portion of the basin at Rainbow Drive in San Jose; it drains an area of 4.9 sq. mi. Gage 26A is in the lower basin at Wilcox High School in Santa Clara, and drains an area of 14.4 sq. mi. Both fifteen-minute and daily flow values were provided by the District. Missing values at each gage were filled by multiplying the other gage flow by the ratio of total flows of the two-gages for the entire 20-year period. Gage 26a was missing 323 days (4.4%) while gage 31 was missing 54 days (0.7%).

## 3.2 WATERSHED SEGMENTATION

Existing land use, slope data, and drainage patterns for the Calabazas watershed divides the area into fourteen subbasins. These subbasins were used as the initial basis for segmentation. The creek was then divided into six reaches whose end points correspond to the subbasin boundaries. (See Figure 3.1). Table 3.4 shows how the subbasins are aggregated into HSPF reach segments. Subbasins H2, I1, and I2 lie below the lower gage and are not simulated.

HSPF requires a function table (or FTABLE) for each stream reach which relates the channel geometry and flow characteristics in piecewise linear fashion, i.e. for a range of selected flow depths, the FTABLE defines the flow rate, channel volume, and surface area. The FTABLES were constructed from HEC-2 input sequences provided by the District, which include channel cross-sections and Manning's n values at various points along Calabazas Creek. The discharges were computed from these data using Manning's equation for open-channel flow programmed within the utility program XSECT2.

The land use and slope data for the subbasins are aggregated for each segment. Four land uses occur in the area being simulated: low-density residential, medium-density residential, commercial, and open. Each of these land uses is represented by an HSPF PERLND (pervious land segment) within each reach segment. The first three land uses are also considered to have an impervious fraction, which is modeled with a corresponding HSPF IMPLND (impervious land segment). The fractions of each land use type assumed to be impervious were taken from a survey of communities within the County, which was supplied by the District. Table 3.5 gives the impervious fraction ranges for the urban land uses.

## Table 3.3 Monthly Class A Pan Evaporation - Los Alamitos Recharge Facility

|  | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PAN FACTOR | 0.75 | 0.70 | 0.65 | 0.60 | 0.70 | 0.70 | 0.75 | 0.75 | 0.80 | 0.80 | 0.80 | 0.75 |  |
| 1959-60 | 3.48 | 1.67 | 1.17 | 0.81 | 1.32 | 2.81 | 4.13 | 5.14 | 7.36 | 6.84 | 6.42 | 4.43 | 45.58 |
| 1960-61 | 2.93 | 1.28 | 0.81 | 0.65 | 1.41 | 2.29 | 4.16 | 4.46 | 5.79 | 7.60 | 5.70 | 4.60 | 41.68 |
| 1961-62 | 3.47 | 1.62 | 0.77 | 1.36 | 1.03 | 2.48 | 4.82 | 5.69 | 7.03 | 7.18 | 4.27 | 4.61 | 44.33 |
| 1962-63 | 2.51 | 1.48 | 0.66 | 0.86 | 1.42 | 2.45 | 3.01 | 4.94 | 7.29 | 6.64 | 6.64 | 4.79 | 42.69 |
| 1963-64 | 2.89 | 1.31 | 0.71 | 1.03 | 1.95 | 3.23 | 5.01 | 5.41 | 6.42 | 7.93 | 7.34 | 5.40 | 48.63 |
| 1964-65 | 3.78 | 1.27 | 0.69 | 0.75 | 1.85 | 2.90 | 3.39 | 6.24 | 6.08 | 6.80 | 6.73 | 4.55 | 45.03 |
| 1965-66 | 3.46 | 1.67 | 1.21 | 1.08 | 1.55 | 2.77 | 4.85 | 5.73 | 7.59 | 7.20 | 7.22 | 5.15 | 49.48 |
| 1966-67 | 3.87 | 1.45 | 0.67 | 1.88 | 1.63 | 2.24 | 2.28 | 5.43 | 5.75 | 7.60 | 6.57 | 4.69 | 44.06 |
| 1967-68 | 3.27 | 1.57 | 1.30 | 0.86 | 0.91 | 2.67 | 4.20 | 5.31 | 7.19 | 7.20 | 6.17 | 4.89 | 45.54 |
| 1968-69 | 2.65 | 1.37 | 0.82 | 0.66 | 1.16 | 2.74 | 3.85 | 5.54 | 5.68 | 7.00 | 6.74 | 4.71 | 42.92 |
| 1969-70 | 3.15 | 1.64 | 1.01 | 0.52 | 1.44 | 3.44 | 4.28 | 5.05 | 7.05 | 7.49 | 6.35 | 5.62 | 47.04 |
| 1970-71 | 2.84 | 1.18 | 0.76 | 0.71 | 1.23 | 2.30 | 3.71 | 4.25 | 6.66 | 6.53 | 6.62 | 5.13 | 41.92 |
| 1971-72 | 2.88 | 1.81 | 0.82 | 0.87 | 1.49 | 3.30 | 3.97 | 4.49 | 4.42 | 4.69 | 4.83 | 2.83 | 36.40 |
| 1972-73 | 2.04 | 0.93 | 0.80 | 1.64 | 1.27 | 2.12 | 4.98 | 5.55 | 6.74 | 7.15 | 6.40 | 4.41 | 44.03 |
| 1973-74 | 3.46 | 1.19 | 0.99 | 0.95 | 1.62 | 2.17 | 4.36 | 5.36 | 6.18 | 6.59 | 6.14 | 4.62 | 43.63 |
| 1974-75 | 3.07 | 1.25 | 1.14 | 1.02 | 2.27 | 3.26 | 3.07 | 5.14 | 5.56 | 5.84 | 5.79 | 3.32 | 40.73 |
| 1975-76 | 2.62 | 1.49 | 1.05 | 1.05 | 1.30 | 2.85 | 4.07 | 5.95 | 7.09 | 6.57 | 5.41 | 4.60 | 44.05 |
| 1976-77 | 3.23 | 1.46 | 0.98 | 0.91 | 1.75 | 3.18 | 5.12 | 4.28 | 6.10 | 7.92 | 6.55 | 6.09 | 47.57 |
| 1977-78 | 3.24 | 1.81 | 0.79 | 0.67 | 1.17 | 2.00 | 3.38 | 6.67 | 6.94 | 7.19 | 6.80 | 4.97 | 45.63 |
| 1978-79 | 3.39 | 1.49 | 0.85 | 0.76 | 1.04 | 1.94 | 4.09 | 6.00 | 7.82 | 7.75 | 6.11 | 4.94 | 46.18 |
| 1979-80 | 3.05 | 1.24 | 0.99 | 0.66 | 1.60 | 2.88 | 3.76 | 4.78 | 6.61 | 6.34 | 5.92 | 4.25 | 42.08 |
| 1980-81 | 3.13 | 1.69 | 0.81 | 0.84 | 1.47 | 2.09 | 4.31 | 5.34 | 7.98 | 8.96 | 6.17 | 4.24 | 47.03 |
| 1981-82 | 2.87 | 1.10 | 0.66 | 0.83 | 1.70 | 1.95 | 3.65 | 5.14 | 5.75 | 6.13 | 5.95 | 4.17 | 39.90 |
| 1982-83 | 2.76 | 1.13 | 1.07 | 1.05 | 1.09 | 1.93 | 3.17 | 5.24 | 6.50 | 7.05 | 5.92 | 4.65 | 41.56 |
| 1983-84 | 2.40 | 1.30 | 0.57 | 0.82 | 1.46 | 3.21 | 4.06 | 6.16 | 6.86 | 7.24 | 6.38 | 5.48 | 45.94 |
| 1984-85 | 2.74 | 1.12 | 0.57 | 0.59 | 1.81 | 2.02 | 4.07 | 4.94 | 6.47 | 6.51 | 5.54 | 3.65 | 40.03 |
| 1985-86 | 2.48 | 1.16 | 0.71 | 0.67 | 1.26 | 2.25 | 3.52 | 4.54 | 6.26 | 6.18 | 4.82 | 3.02 | 36.87 |
| 1986-87 | 2.61 | 1.46 | 0.69 | 0.91 | 1.55 | 2.42 | 4.31 | 4.66 | 6.28 | 6.00 | 5.45 | 3.82 | 40.16 |
| 1987-88 | 2.48 | 0.84 | 1.07 | 0.76 | 1.82 | 3.34 | 3.43 | 5.19 | 5.88 | 5.94 | 6.25 | 3.85 | 40.85 |
| 1988-89 | 2.32 | 1.04 | 0.80 | 0.69 | 1.12 | 1.89 | 3.41 | 5.21 | 5.97 | 6.62 | 5.30 | 3.29 | 37.66 |
| 1989-90 | 2.34 | 1.11 | 0.58 | 0.82 | 1.11 | 2.08 | 3.59 | 4.76 | 5.76 | 6.08 | 5.31 | 3.36 | 36.90 |
| 1990-91 | 2.72 | 1.42 | 0.49 | 0.60 | 1.04 | 2.12 | 3.57 | 4.23 | 5.43 | 6.07 | 4.77 | 3.62 | 36.08 |
| 1991-92 | 2.50 | 1.20 | 0.99 | 0.56 | 0.81 | 1.53 | 3.62 | 4.59 | 5.46 | 5.66 | 5.08 | 3.57 | 35.57 |
| 1992-93 | 2.06 | 1.07 | 0.75 | 0.65 | 1.14 | 1.99 | 3.35 | 3.80 | 6.22 | 5.66 | 5.71 | 3.35 | 35.75 |
| 1993-94 | 2.14 | 1.39 | 0.55 | 0.60 | 0.79 | 2.09 | 2.81 | 3.87 | 5.87 | 5.02 | 5.50 | 3.32 | 33.95 |
| 1994-95 | 2.12 | 0.82 | 0.51 | 0.50 | 0.79 | 1.45 | 2.90 | 3.49 | 6.43 | 6.50 | 6.02 | 3.83 | 35.35 |
| 1995-96 | 2.83 | 1.06 | 0.60 | 0.73 | 1.10 | 2.40 | 3.67 |  |  |  |  |  | 12.39 |
| AVERAGE | 2.86 | 1.35 | 0.84 | 0.86 | 1.39 | 2.48 | 3.87 | 5.12 | 6.40 | 6.72 | 5.97 | 4.34 | 42.21 |

## Table 3.4 Calabazas Creek Watershed Reach Segmentation

| Reach | Tributary subbasins | Reach endpoint |
|---|---|---|
| 1 | A | Southern Pacific RR |
| 2 | C,D1 | Rainbow Drive (Gage 31) |
| 3 | B1,B2,D2,E1,E2 | Below Regnart Creek |
| 4 | F | Interstate 280 |
| 5 | G | El Camino Real |
| 6 | H1 | Wilcox HS (Gage 26A) |

### Table 3.5 Impervious Fraction of Urban Land Uses

| | |
|---|---|
| Low-Density Residential | 20 - 45% |
| Medium-Density Residential | 45 - 70% |
| Commercial | 85 - 95% |

Not all subbasins contain all land uses, so only 23 of a possible 42 simulation units (six segments times seven land uses) were required. Table 3.6 shows the resulting land use areas for each segment.

### Table 3.6 Land Use Areas in Acres by Basin Segment

| | Segment | | | | | |
|---|---|---|---|---|---|---|
| Land Use | 1 | 2 | 3 | 4 | 5 | 6 |
| Low-Density Residential 40% Impervious | 727.04 | 591.36 | 1411.84 | - | 555.52 | - |
| Medium-Density Residential 65% Impervious | - | - | 1816.32 | 610.56 | 555.52 | 300.80 |
| Commercial 95% Impervious | - | - | - | 407.04 | 277.76 | - |
| Open All Pervious | 1090.56 | 727.04 | 157.44 | - | - | - |

The precipitation data for each reach segment is a weighted average of the rainfall stations according to the Thiessen network, with a multiplier based on comparison with an isohyetal map provided by the District. The Los Alamitos potential evaporation dataset is used throughout the basin without modification.

Examination of soil maps provided by the District showed two general regions corresponding to the upper and lower portions of the basin. The variability of soil characteristics within each region is on the same order as the variability between regions. The dividing line between upland and lowland soil groups is close enough to the drainage boundary for the upper gage to allow separate calibration parameters, and no further segmentation based on soils was considered necessary.

## 3.3 HYDROLOGY CALIBRATION AND VERIFICATION

### 3.3.1 Hydrologic Calibration of Calabazas Creek

The hydrology calibration process was performed with the aide of HSPEXP, an expert system developed by AQUA TERRA and others for the USGS (Lumb, McCammon, and Kittle,

1994) specifically designed for use with HSPF. This package gives calibration advice, such as which model parameters to adjust and/or input to check, based on predetermined rules, and allows the user to interactively modify the HSPF Users Control Input (UCI) files, make model runs, examine statistics, and generate a variety of plots.. HSPEXP still has some limitations, such as 'how much' to change a parameter and relative differences among land uses, which require professional modeling experience and judgement, but it has greatly facilitated the calibration process and is an excellent tool for both beginners and experienced modelers.

The hydrology calibrations were performed for the 10-year period from July 1982 through June 1992, and the results are tabulated based on the local rainfall year i.e. July through June. After obtaining reasonable results for the calibration period, model runs were performed for the entire 20-year record with the 1973-82 period used for verification.

The hydrology calibration results are presented in the following tables and figures, for each gage site -- Gage #26a at Wilcox High School and Gage #31 at Rainbow Drive -- in the order shown below:

| | |
|---|---|
| Table 3.7 | Calabazas Creek Hydrologic Calibration: Comparison of Total Annual Observed vs Simulated Flow |
| Figure 3.2 | Calabazas Creek Hydrology Calibration, Wilcox High School - Average Monthly Flow, 1982-92 |
| Figure 3.3 | Calabazas Creek Hydrology Calibration, Rainbow Drive - Average Monthly Flow, 1982-92 |
| Figure 3.4 | Flow Frequency for Calabazas Creek Hydrology Calibration, Wilcox High School, 1982-92 |
| Figure 3.5 | Flow Frequency for Calabazas Creek Hydrology Calibration, Rainbow Drive, 1982-92 |

Appendix A includes daily flow comparisons for each of the ten years of the calibration period for each gage site.

The volume comparison in Table 3.7 generally shows very good agreement for the entire simulation period, as shown by the agreement between the mean annual runoff amounts, but, as expected there is more variability in individual years. The Gage #26a values are somewhat over-simulated, primarily in an attempt to increase the simulated peaks as shown in the flow frequency results (discussed below); whereas the Gage #31 values show closer agreement for the total runoff values.

The monthly flow comparisons in Figures 3.2 and 3.3 show agreement similar to, and consistent with, the annual results; high flow years are somewhat under simulated and the low flow years are slightly over-simulated. However, the overall pattern is a reasonably good representation of the monthly flow regime.

The flow frequency curves (actually flow-duration curves) in Figures 3.4 and 3.5 for the calibration period (1982-92) demonstrate similar patterns for both sites, but there are some deviations from the observed shape. The baseflow portions of the curves are under-simulated at both sites. This corresponds to very low flows less than about 0.5 cfs for the Wilcox gage and less than about 4.0 cfs at the Rainbow gage. Obviously, there is some loss of baseflow to the underlying soil of the channel between the two gages. It was not possible to accurately model these low flow periods, especially during the dry summer months, because the observed data showed an irregular pattern of low flows mostly during periods of no rainfall (see the daily flow plots in Appendix A). These flows seem to be due to irrigation (lawn watering) and possibly undocumented point sources. The point sources for which data were available (i.e. from the Loads Assessment report) were too small to account for these flows. Our field visit showed significant areas of lawn watering and baseflows resulting from the added water. Since our focus is on storm flows we discounted these low flow deviations as not being of importance for this study. In other HSPF applications we have developed procedures to include lawn watering and agricultural irrigation, but this requires a significantly greater effort than planned for this study.

All the plots show a slight under-simulation of peak flows (i.e less than 1% exceedance), and some over-simulation of mid-range flows generally at flow rates less than 200 cfs. There appears to be a 'dip' in the observed frequency curve, whereas the simulated curve is more linear on the log-probability plot. It appears that the non-rainfall contributions to baseflow (noted above) start to impact the flows in this region and thus change the normal or expected slope of the curve, leading to more sustained flows at the low range.

The daily flow plots in Appendix A are difficult to analyze due to the annual time scale with daily flows plotted, and the fact that the vertical scale changes from year to year; however, we have included them to be complete and to demonstrate additional aspects of the simulation:

a. The daily hydrograph shape is well represented as shown by both the flow recession and the response to rainfall inputs, shown in the auxiliary plot above the flow curve.

b. The baseflow issue is evident from the sustained, but sometimes erratic, low flows during long periods without rainfall, especially during the summer months. This is most obvious at the Rainbow gage during dry years, such as 1986-1988, and the constant baseflows are often sustained throughout the winter. For the water quality simulation, to avoid numerical problems with concentration values (as flow approaches zero) we input a minimal constant point flow of 0.2 cfs (see Section 3.5 below).

c. The simulation for 1988-89 seems to be especially inaccurate, with most of the flows over-simulated. However, there is also evidence of timing problems either with the

## TABLE 3.7 CALABAZAS CREEK HYDROLOGIC CALIBRATION: COMPARISON OF TOTAL ANNUAL OBSERVED vs SIMULATED FLOW

**SCVWD GAGE # 26a AT WILCOX HIGH SCHOOL (RCHRES 6)**

| WATER YEAR | OBSERVED FLOW (in) | SIMULATED FLOW (in) | PRECIPITATION (in) |
|---|---|---|---|
| 1982-83 | 33.42 | 32.00 | 47.61 |
| 1983-84 | 8.74 | 10.61 | 19.22 |
| 1984-85 | 5.32 | 7.37 | 17.29 |
| 1985-86 | 23.28 | 20.91 | 32.09 |
| 1986-87 | 3.32 | 3.97 | 11.88 |
| 1987-88 | 3.57 | 5.28 | 14.26 |
| 1988-89 | 1.79 | 3.83 | 11.22 |
| 1989-90 | 3.18 | 4.49 | 13.11 |
| 1990-91 | 5.90 | 8.40 | 17.30 |
| 1991-92 | 10.83 | 13.80 | 23.30 |
| MEAN | 9.94 | 11.07 | 20.87 |

**SCVWD GAGE # 31 AT RAINBOW DRIVE (RCHRES 2)**

| WATER YEAR | OBSERVED FLOW (in) | SIMULATED FLOW (in) | PRECIPITATION (in) |
|---|---|---|---|
| 1982-83 | 47.95 | 42.96 | 62.81 |
| 1983-84 | 11.85 | 13.87 | 27.86 |
| 1984-85 | 5.91 | 8.80 | 22.59 |
| 1985-86 | 28.23 | 26.29 | 41.06 |
| 1986-87 | 5.48 | 4.27 | 15.53 |
| 1987-88 | 6.39 | 5.95 | 18.95 |
| 1988-89 | 3.72 | 5.10 | 16.33 |
| 1989-90 | 2.90 | 4.54 | 17.71 |
| 1990-91 | 6.77 | 11.05 | 23.65 |
| 1991-92 | 14.68 | 17.36 | 30.79 |
| MEAN | 13.38 | 14.02 | 27.73 |

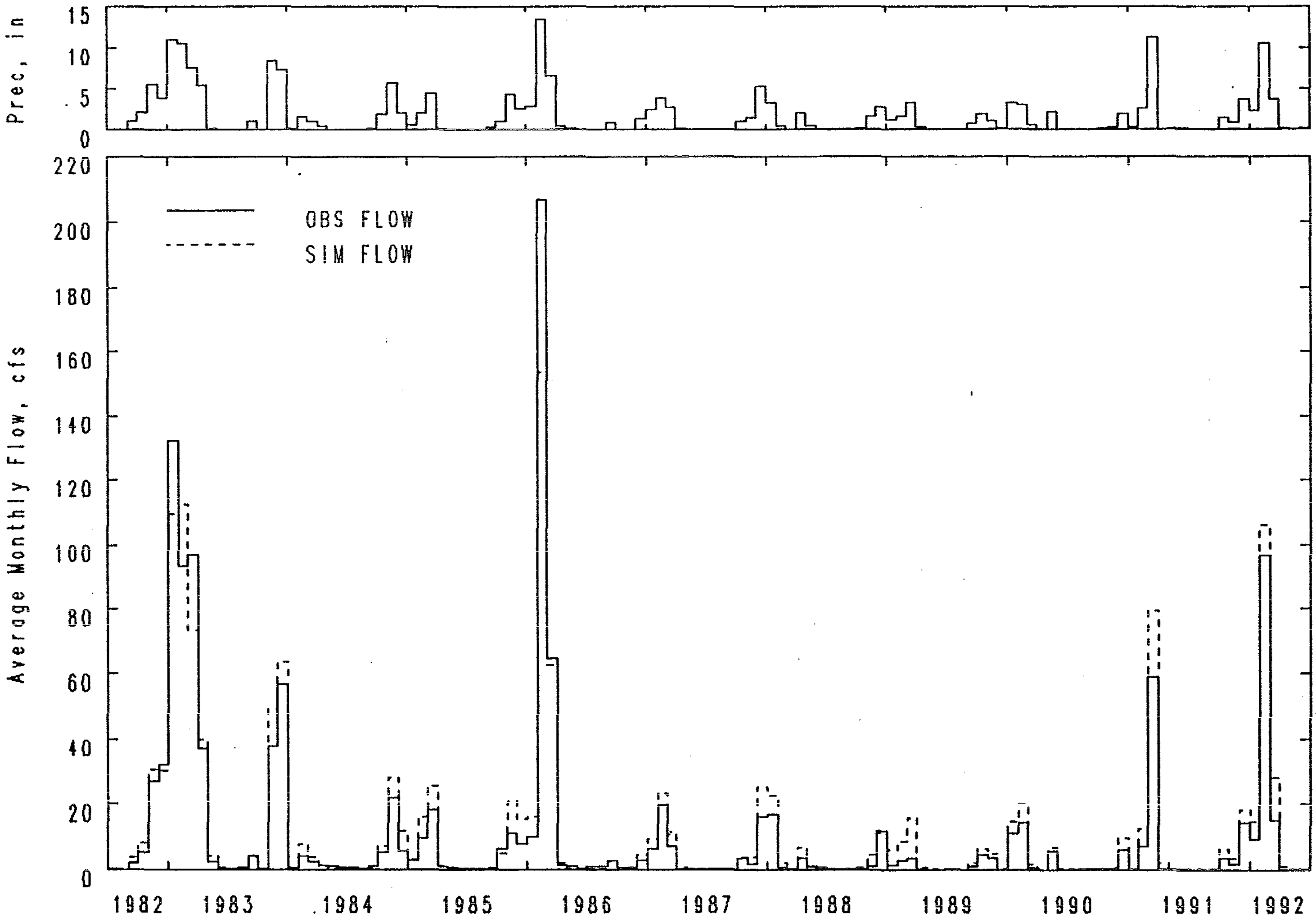

Figure 3.2 Calabazas Creek Hydrology Calibration
Wilcox High School - Average Monthly Flow, 1982-92

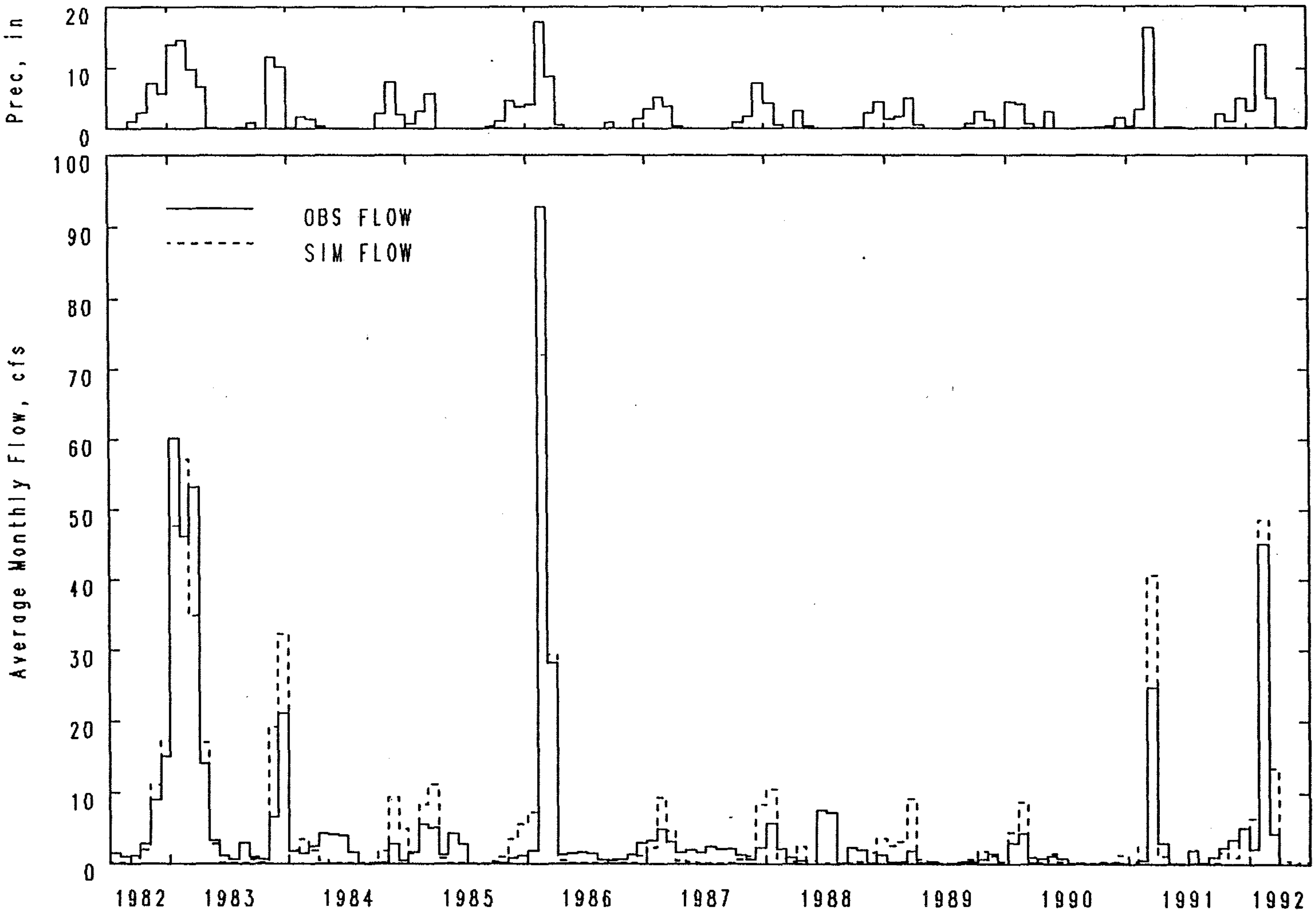

Figure 3.3 Calabazas Creek Hydrology Calibration
Rainbow Drive - Average Monhthly Flow, 1982-92

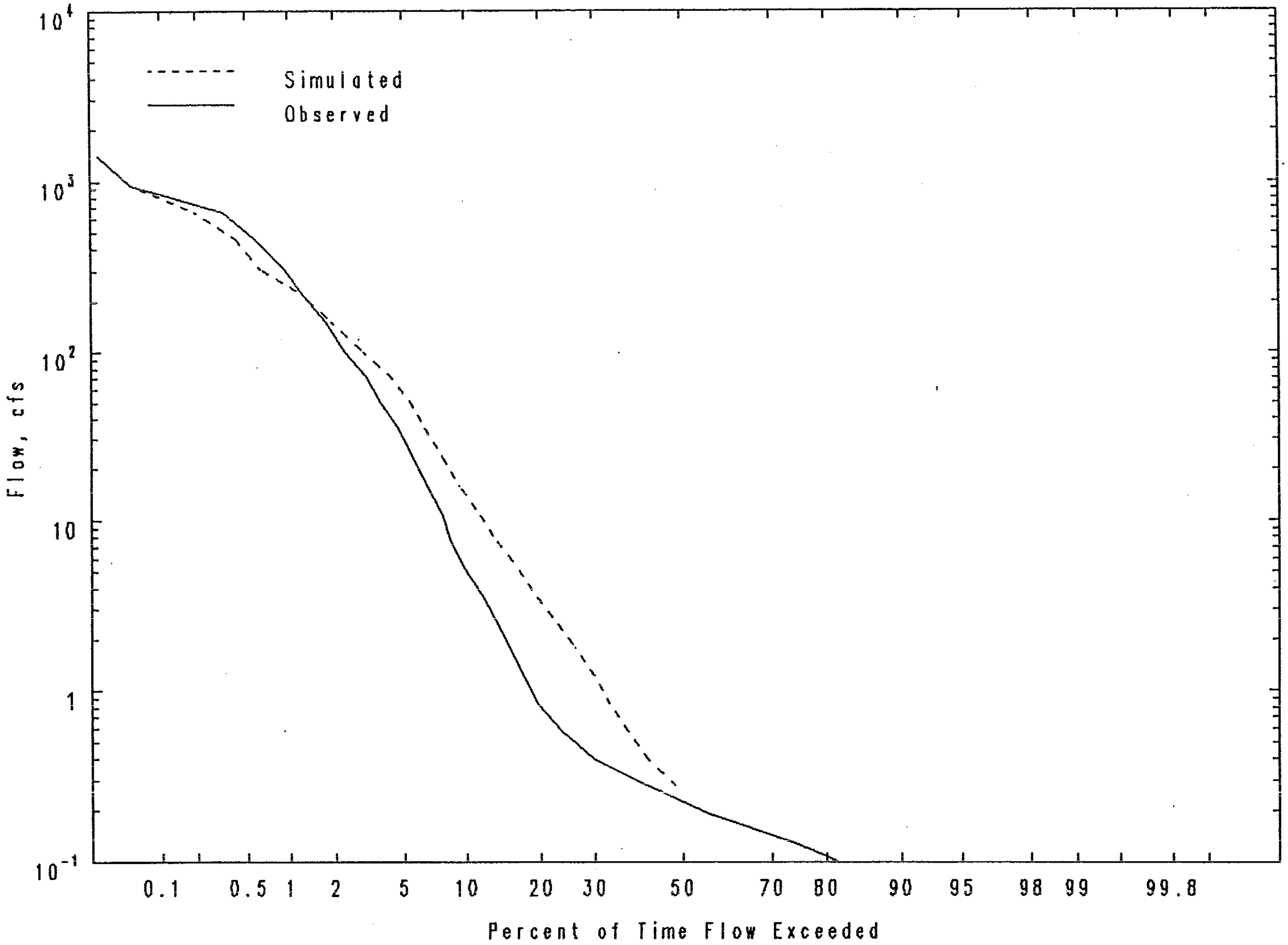

Figure 3.4 Flow Frequency for Calabazas Creek Hydrology Calibration
Wilcox High School, 1982-92

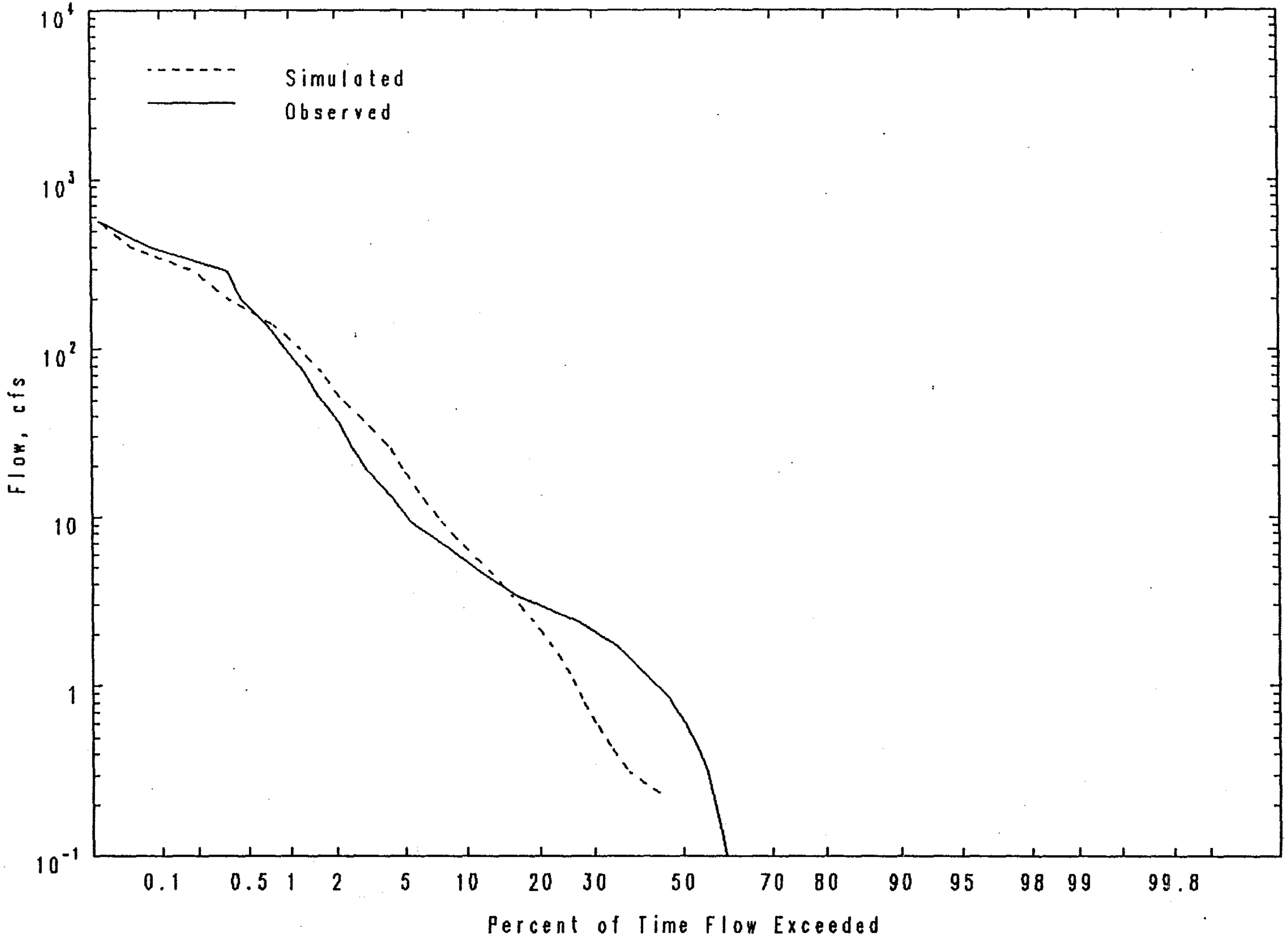

Figure 3.5 Flow Frequency for Calabazas Creek Hydrology Calibration
Rainbow Drive, 1982-92

observed rainfall or flow, such as the observed flow during early December 1988 when the last rainfall was almost two weeks earlier.

### 3.3.2 Hydrologic Verification of Calabazas Creek

Following the hydrologic calibration, the entire 20-year period from 1972 to 1992 was simulated with the earlier 1972-82 period used for verification. Table 3.8 and Figures 3.6 through 3.9 show the verification results analogous to the calibration results presented earlier, and Appendix A includes the daily flow comparisons for the verification period. Comparing these model results with those from the calibration period indicate that the model is performing at an equal level of agreement with the observed data for both time periods. The annual runoff values and monthly patterns are well represented and are in good agreement with observations. The magnitude and shapes of the frequency curves are similar and consistent for both periods and demonstrate the same agreement with the observed curves.

Although further refinement of the model results may be possible, through use of a 15-minute timestep, further analysis of rainfall spatial variation, and additional calibration, we feel the overall calibration and verification has been demonstrated to be successful. The model results are reasonable and provide a sound basis for the subsequent sediment and water quality simulations in this study.

## 3.4 NONPOINT LOAD CALIBRATION

Following the hydrology calibration and verification, the nonpoint loads were simulated and calibrated to available data and estimates of loading rates from local information and past modeling experience. The nonpoint load simulation involved calculation of loading rates for each land use category for sediment, copper, and BOD, along with simulation of the DO input associated with surface and subsurface flow components. Table 3.9 shows the mean loading rates and percent contributions for each model segment, and each land use within a segment, for the calibration periods for sediment, copper, and BOD. Note that the sediment rates are in units of 'tons/acre/year' while the copper and BOD rates are 'pounds/acre/year'. In the following subsections we discuss the parameter estimation and calibration procedures for each of the three nonpoint constituents. Although the model requires NPS loads by land use, this study did not focus on assigning copper sources among the land use categories.

Simulation of instream processes requires water temperature values which are normally simulated with HSPF using meteorologic input data and a detailed energy balance approach. For this study, we used **observed** water temperature data from numerous streams in the region, calculated mean monthly temperatures, and input these values into the model as the temperature of the flows into the stream channel. DO contributions to the stream are specified separately for surface runoff and subsurface flow components; surface runoff is assumed to contribute DO at its saturation value, while the subsurface concentrations are defined by the user in the form of mean monthly values estimated from other streams in the region.

## TABLE 3.8 CALABAZAS CREEK HYDROLOGY VERIFICATION: COMPARISON OF TOTAL ANNUAL OBSERVED vs SIMULATED FLOW

**SCVWD GAGE # 26A AT WILCOX HIGH SCHOOL (RCHRES 6)**

| WATER YEAR | OBSERVED FLOW(IN) | SIMULATED FLOW (IN) | RAINFALL (IN) |
|---|---|---|---|
| 1972-73 | 15.93 | 18.24 | 32.81 |
| 1973-74 | 10.55 | 11.94 | 25.91 |
| 1974-75 | 9.68 | 10.34 | 23.01 |
| 1975-76 | 3.36 | 1.86 | 8.46 |
| 1976-77 | 1.82 | 2.80 | 11.03 |
| 1977-78 | 18.59 | 23.77 | 35.96 |
| 1978-79 | 6.43 | 9.22 | 19.44 |
| 1979-80 | 16.77 | 18.99 | 31.73 |
| 1980-81 | 4.99 | 7.34 | 16.32 |
| 1981-82 | 19.29 | 21.74 | 35.83 |
| MEAN | 10.74 | 12.62 | 24.05 |

**SCVWD GAGE # 31 AT RAINBOW DRIVE (RCHRES 2)**

| WATER YEAR | OBSERVED FLOW(IN) | SIMULATED FLOW (IN) | RAINFALL (IN) |
|---|---|---|---|
| 1972-73 | 29.25 | 23.46 | 42.40 |
| 1973-74 | 17.26 | 14.75 | 33.08 |
| 1974-75 | 20.22 | 12.94 | 30.30 |
| 1975-76 | 7.01 | 1.62 | 10.86 |
| 1976-77 | 3.12 | 2.23 | 13.98 |
| 1977-78 | 20.10 | 31.63 | 48.10 |
| 1978-79 | 4.61 | 12.04 | 26.59 |
| 1979-80 | 22.00 | 25.24 | 42.68 |
| 1980-81 | 5.70 | 9.09 | 21.64 |
| 1981-82 | 25.18 | 31.15 | 49.29 |
| MEAN | 15.44 | 16.41 | 31.89 |

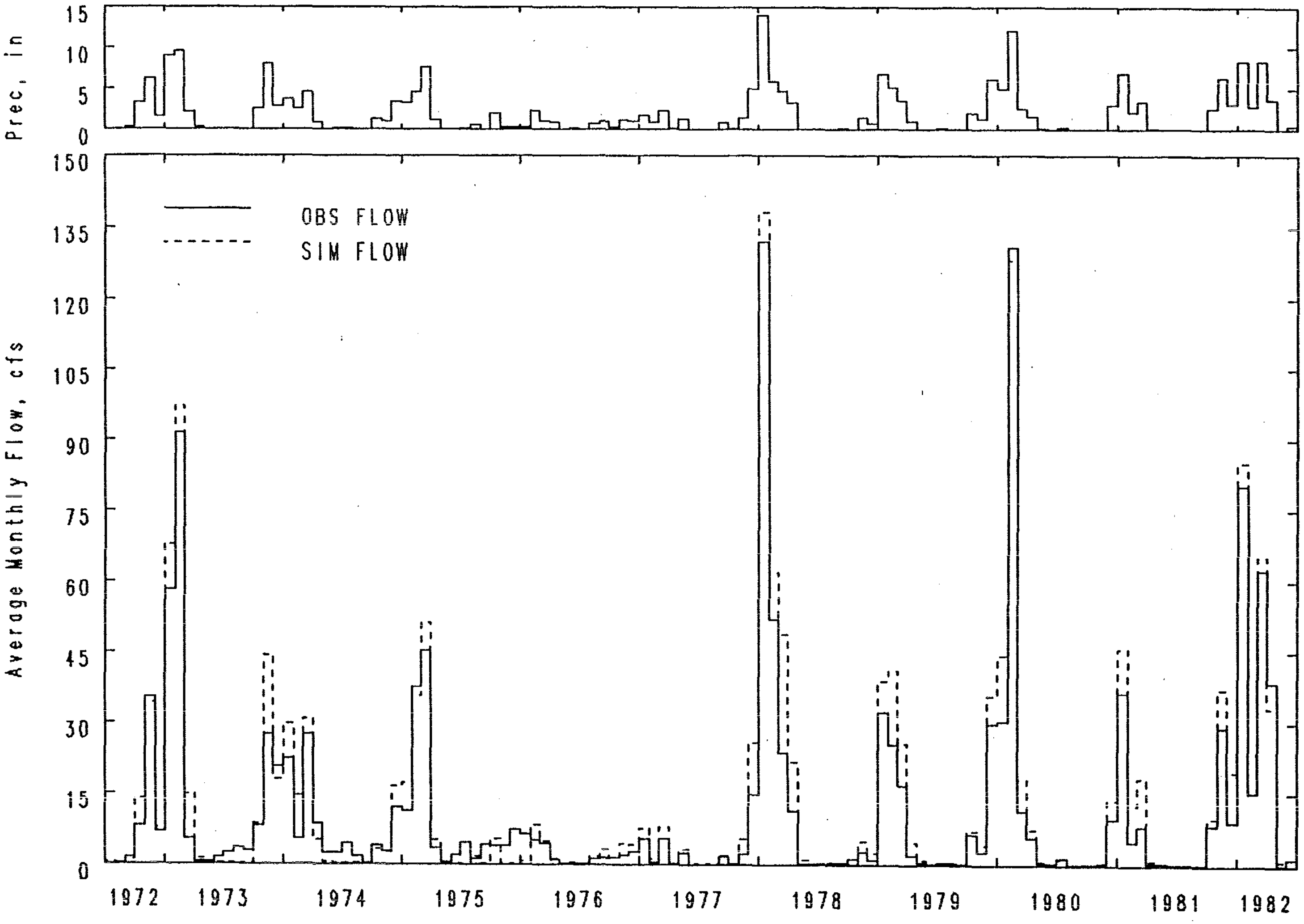

Figure 3.6 Calabazas Creek Hydrology Verification
Wilcox High School - Average Monthly Flow, 1972-1982

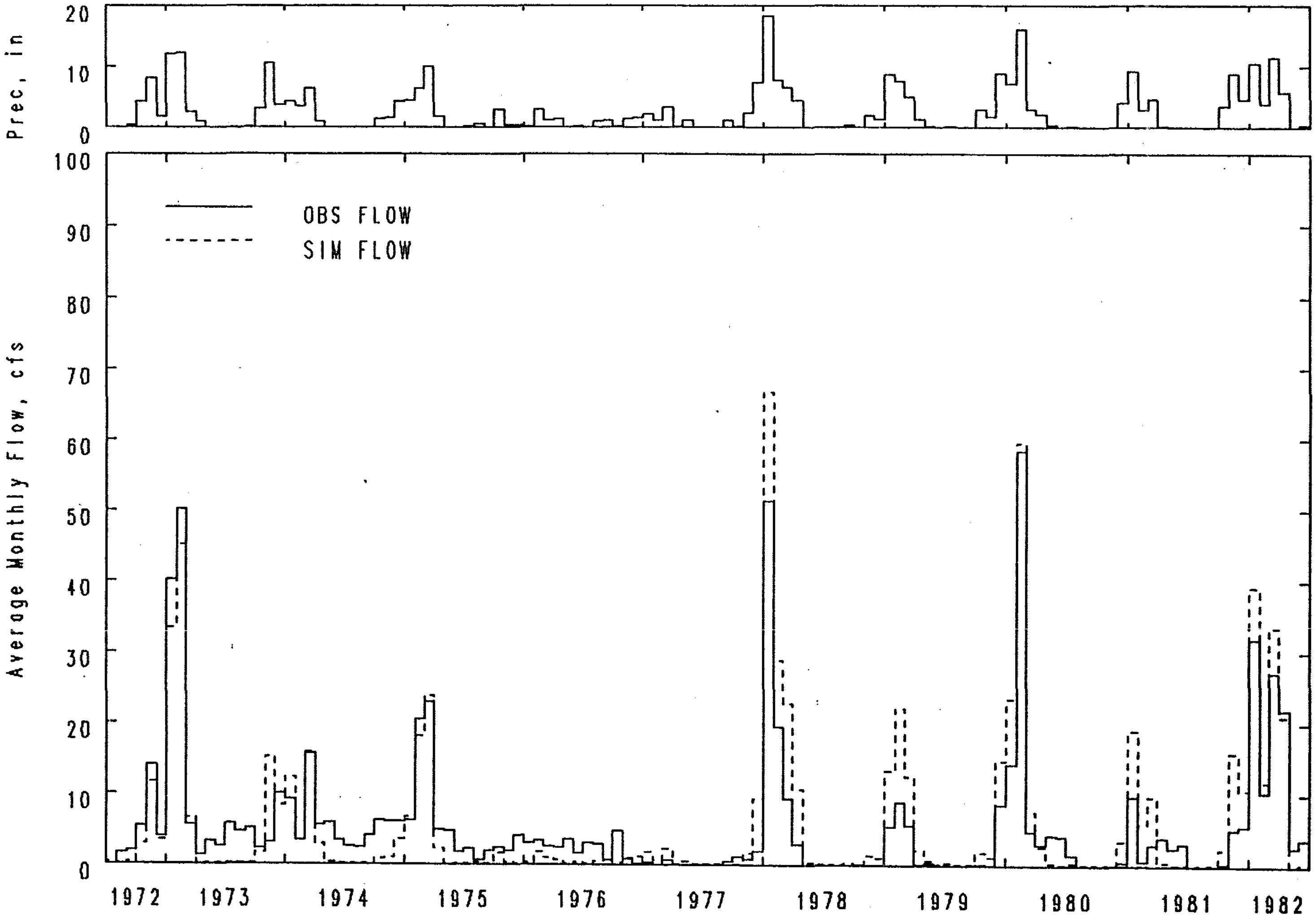

Figure 3.7 Calabazas Creek Hydrology Verification
Rainbow Drive - Average Monthly Flow, 1972-1982

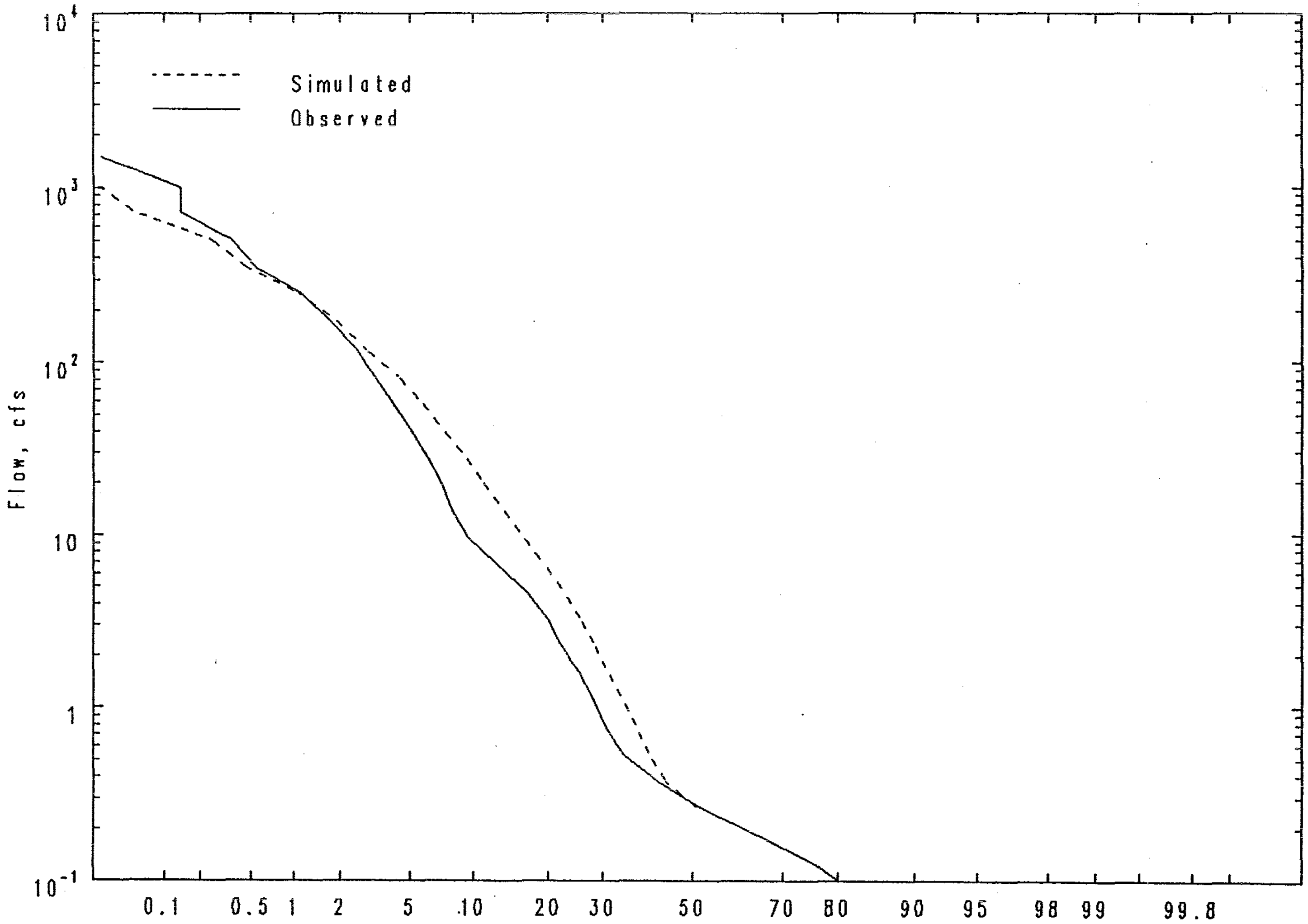

Figure 3.8 Flow Frequency for Calabazas Creek Hydrology Verification
Wilcox High School, 1972-82

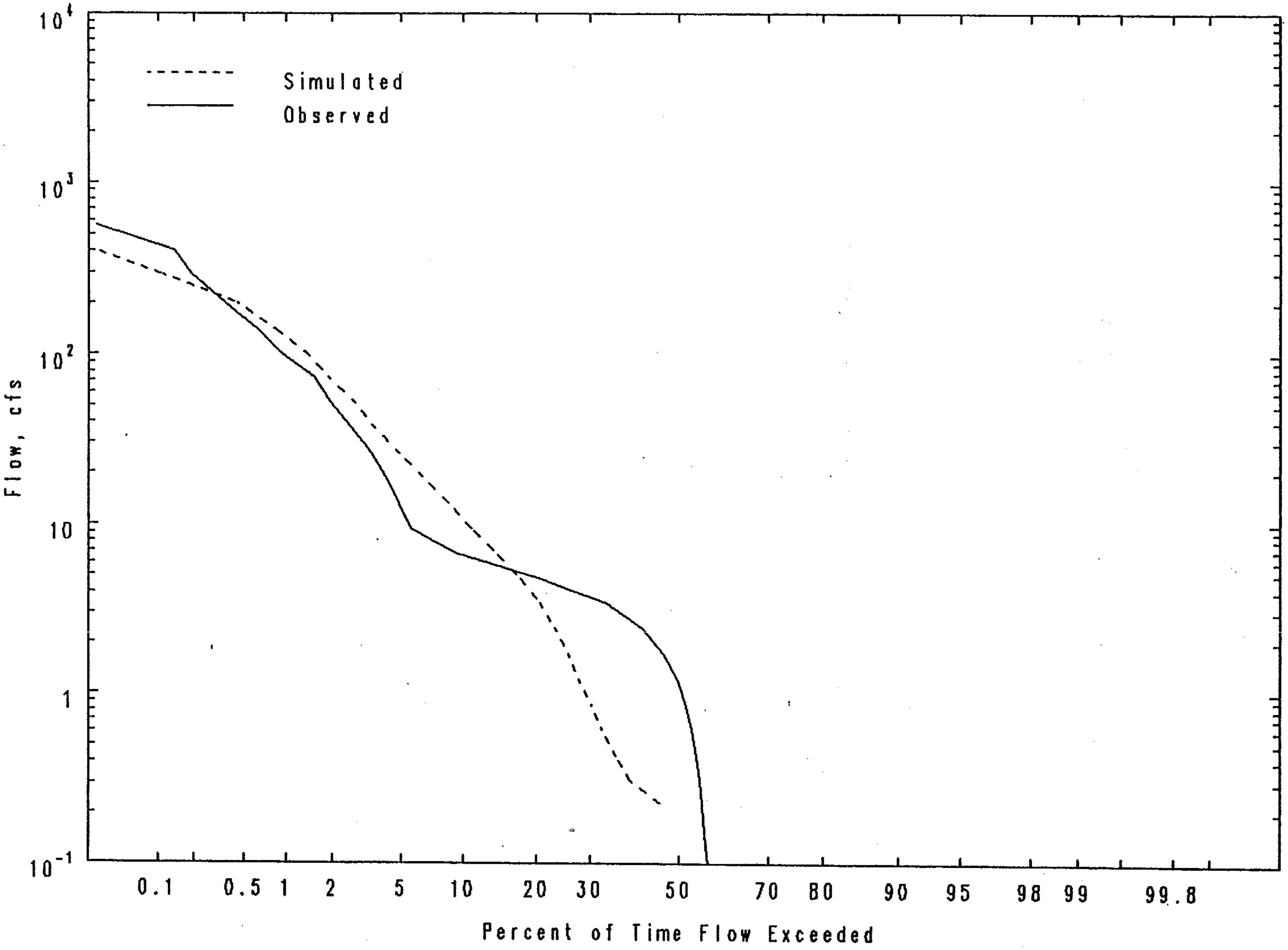

Figure 3.9 Flow Frequency for Calabazas Creek Hydrology Verification
Rainbow Drive, 1972-82

### 3.4.1 Sediment Loading Rates

The sediment loading rates represent the contributions to each channel reach from the land surface of all the land uses in the watershed, including separate contributions from both pervious and impervious portions. To help guide the calibration, we developed 'target' rates from local data and information and then calibrated the relevant sediment model parameters so that the simulated values were in the range of the target values. In Table 3.9, the mean rates for sediment are for the same 10-year period as the hydrologic calibration, i.e. 1982-92, while the copper and BOD rates are for the 5-year period of the water quality calibration, 1987-92.

Table 3.10 shows a summary comparison of the simulated rates with the target values for each land use and for both pervious and impervious portions. The target values were developed by a combination of procedures. For the pervious areas, the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) was applied with land use, slope, and local soils and climatic information provided by the District and from the NRCS (B. Eisenman, USDA-NRCS, Hollister, CA, personal communication, 1996). These estimates were adjusted with a range of potential 'delivery ratios' to determine the target, or expected, loading rates for input to the stream channel. Calculations were also performed using mean TSS concentrations reported by WCC (1991) and expected ranges of annual runoff from rainfall as an additional check and refinement of the sediment loading estimates. For the impervious areas, similar calculations were performed with a range of TSS concentrations, runoff coefficients and rainfall amounts for the Calabazas watershed to provide the target ranges shown in Table 3.10.

The higher values in Table 3.10 correspond to the areas with the highest slopes and rainfall amounts in the upper portions of the watershed. The pervious residential and commercial rates are generally low since they normally represent rates from turf and lawn-type conditions with almost complete grass cover and very little surface runoff (Schueler, 1995), while the open areas have rates that can approach values for agriculture due to lack of extensive or complete vegetal cover. For the impervious areas, the residential rates for both low and medium density are similar, whereas the commercial rates are usually somewhat higher due to increased activities and automobile traffic. In the lower segments, impervious rates are higher than the pervious values due to high runoff and traffic on the impervious surfaces.

### 3.4.2 Copper Loading Rates

Loading rates for copper are modeled in HSPF as a function of the sediment rates for surface runoff and by user-defined concentrations for contributions in subsurface flow (i.e. interflow and baseflow). Parameters, referred to as 'Potency Factors' in the model, specify the amount of copper associated with the sediment load entering the stream. For the pervious areas, these values were estimated initially from average soil copper concentrations from the upland portions of the watershed (presented in WCC, 1996a) representing the 'open' land use category. The values were then adjusted for the other pervious land uses based on the relative ratios of surface runoff copper concentrations at the land use monitoring sites as

# Table 3.9 Summary of Mean Loading Rates and Percent Contributions for Sediment, Copper, and BOD for all Model Segments

**MEAN LOADING RATES FOR EACH LAND USE**

**Sediment - (tons/ac)**

| | | Pervious | | | | Impervious | | | Total Load |
|---|---|---|---|---|---|---|---|---|---|
| | | LDR | MDR | COM | OPN | LDR | MDR | COM | |
| Segment | 10 | 0.490 | 0.0 | 0.0 | 1.235 | 0.450 | 0.0 | 0.0 | 0.930 |
| Segment | 20 | 0.320 | 0.0 | 0.0 | 0.800 | 0.310 | 0.0 | 0.0 | 0.582 |
| Segment | 30 | 0.190 | 0.190 | 0.0 | 0.620 | 0.220 | 0.280 | 0.0 | 0.240 |
| Segment | 40 | 0.0 | 0.160 | 0.160 | 0.0 | 0.0 | 0.300 | 0.500 | 0.343 |
| Segment | 50 | 0.110 | 0.110 | 0.120 | 0.0 | 0.220 | 0.290 | 0.430 | 0.235 |
| Segment | 60 | 0.0 | 0.130 | 0.0 | 0.0 | 0.0 | 0.290 | 0.0 | 0.234 |

**Copper - (lbs/ac)**

| | | Pervious | | | | Impervious | | | Total Load |
|---|---|---|---|---|---|---|---|---|---|
| | | LDR | MDR | COM | OPN | LDR | MDR | COM | |
| Segment | 10 | 0.126 | 0.0 | 0.0 | 0.135 | 0.168 | 0.0 | 0.0 | 0.138 |
| Segment | 20 | 0.078 | 0.0 | 0.0 | 0.082 | 0.100 | 0.0 | 0.0 | 0.084 |
| Segment | 30 | 0.038 | 0.049 | 0.0 | 0.056 | 0.070 | 0.121 | 0.0 | 0.074 |
| Segment | 40 | 0.0 | 0.041 | 0.051 | 0.0 | 0.0 | 0.151 | 0.283 | 0.176 |
| Segment | 50 | 0.022 | 0.030 | 0.042 | 0.0 | 0.090 | 0.167 | 0.280 | 0.121 |
| Segment | 60 | 0.0 | 0.042 | 0.0 | 0.0 | 0.0 | 0.168 | 0.0 | 0.124 |

**BOD - (lbs/ac)**

| | | Pervious | | | | Impervious | | | Total Load |
|---|---|---|---|---|---|---|---|---|---|
| | | LDR | MDR | COM | OPN | LDR | MDR | COM | |
| Segment | 10 | 9.70 | 0.0 | 0.0 | 8.08 | 16.84 | 0.0 | 0.0 | 9.87 |
| Segment | 20 | 6.71 | 0.0 | 0.0 | 5.77 | 14.52 | 0.0 | 0.0 | 7.592 |
| Segment | 30 | 3.02 | 4.88 | 0.0 | 3.84 | 14.08 | 16.88 | 0.0 | 10.09 |
| Segment | 40 | 0.0 | 3.99 | 6.04 | 0.0 | 0.0 | 16.28 | 21.70 | 15.55 |
| Segment | 50 | 1.83 | 2.98 | 4.96 | 0.0 | 13.10 | 15.72 | 20.96 | 11.07 |
| Segment | 60 | 0.0 | 4.03 | 0.0 | 0.0 | 0.0 | 16.94 | 0.0 | 12.42 |

Note: Sediment Loading Rates Are Based On 10-year Calibration; Copper and BOD Rates Are Based On 5-year Calibration

**PERCENT OF TOTAL LOAD CONTRIBUTED FROM EACH LANDUSE**

**Sediment - (%)**

| | | Pervious | | | | Impervious | | | Total Load |
|---|---|---|---|---|---|---|---|---|---|
| | | LDR | MDR | COM | OPN | LDR | MDR | COM | |
| Segment | 10 | 11.94 | 0.0 | 0.0 | 80.91 | 7.15 | 0.0 | 0.0 | 100.0 |
| Segment | 20 | 14.15 | 0.0 | 0.0 | 77.61 | 8.24 | 0.0 | 0.0 | 100.0 |
| Segment | 30 | 17.41 | 13.08 | 0.0 | 13.19 | 15.65 | 40.67 | 0.0 | 100.0 |
| Segment | 40 | 0.0 | 7.71 | 0.79 | 0.0 | 0.0 | 35.24 | 56.25 | 100.0 |
| Segment | 50 | 8.48 | 4.95 | 0.43 | 0.0 | 15.72 | 34.00 | 36.43 | 100.0 |
| Segment | 60 | 0.0 | 16.90 | 0.0 | 0.0 | 0.0 | 83.10 | 0.0 | 100.0 |

**Copper - (%)**

| | | Pervious | | | | Impervious | | | Total Load |
|---|---|---|---|---|---|---|---|---|---|
| | | LDR | MDR | COM | OPN | LDR | MDR | COM | |
| Segment | 10 | 21.88 | 0.0 | 0.0 | 58.72 | 19.40 | 0.0 | 0.0 | 100.0 |
| Segment | 20 | 24.82 | 0.0 | 0.0 | 53.82 | 21.36 | 0.0 | 0.0 | 100.0 |
| Segment | 30 | 11.73 | 12.37 | 0.0 | 3.52 | 15.61 | 56.76 | 0.0 | 100.0 |
| Segment | 40 | 0.0 | 4.92 | 0.58 | 0.0 | 0.0 | 33.46 | 61.03 | 100.0 |
| Segment | 50 | 4.31 | 3.51 | 0.35 | 0.0 | 11.88 | 35.96 | 44.00 | 100.0 |
| Segment | 60 | 0.0 | 12.00 | 0.0 | 0.0 | 0.0 | 88.00 | 0.0 | 100.0 |

**BOD - (%)**

| | | Pervious | | | | Impervious | | | Total Load |
|---|---|---|---|---|---|---|---|---|---|
| | | LDR | MDR | COM | OPN | LDR | MDR | COM | |
| Segment | 10 | 23.58 | 0.0 | 0.0 | 49.11 | 27.30 | 0.0 | 0.0 | 100.0 |
| Segment | 20 | 23.77 | 0.0 | 0.0 | 41.91 | 34.31 | 0.0 | 0.0 | 100.0 |
| Segment | 30 | 7.49 | 9.09 | 0.0 | 1.77 | 23.29 | 58.36 | 0.0 | 100.0 |
| Segment | 40 | 0.0 | 5.38 | 0.78 | 0.0 | 0.0 | 40.82 | 53.02 | 100.0 |
| Segment | 50 | 3.97 | 3.77 | 0.45 | 0.0 | 18.93 | 36.92 | 35.97 | 100.0 |
| Segment | 60 | 0.0 | 11.35 | 0.0 | 0.0 | 0.0 | 88.65 | 0.0 | 100.0 |

**Table 3.10 Simulated and Target Sediment Loading Rates, T/ac/yr**

| LAND USE | SIMULATED VALUES | TARGET RANGE |
|---|---|---|
| Pervious | | |
| Low Density Residential | 0.11 - 0.49 | 0.05 - 0.50 |
| Medium Density Residential | 0.11 - 0.19 | 0.05 - 0.20 |
| Commercial | 0.12 - 0.16 | 0.10 - 0.20 |
| Open | 0.62 - 1.24 | 0.50 - 2.00 |
| Impervious | | |
| Low Density Residential | 0.22 - 0.45 | 0.10 - 0.50 |
| Medium Density Residential | 0.28 - 0.30 | 0.10 - 0.50 |
| Commercial | 0.43 - 0.50 | 0.20 - 0.50 |

presented by WCC (Monitoring Data Analysis Report, draft June,1996), i.e. we increased the potency factors by the relative increase in surface runoff concentrations for each land use as compared to the open land use category. An additional adjustment was made, by a factor of 2.0, to represent the 'enrichment' process that increases the fine particles in the surface erosion load as compared to the particle distribution of the soil matrix.

The potency factors for the impervious areas were increased 50% more than the pervious area factors to reflect recent reports that much of the urban copper nonpoint load is derived from automobile related sources (WCC, 1996a; Moran, 1997; Sansalone and Buchberger, 1997), which would be associated with impervious land surfaces. However, this study did not attempt to attribute copper sources to specific land uses; the goal was to represent the total load and resulting instream concentrations.

The subsurface copper concentrations were estimated from water supply and source data presented by WCC (1996a). The lowest values were for the open areas and were set to 1.0 ug/l corresponding to measured water supply values. The values were increased for the residential and commercial land uses, up to 5.0 to 10.0 ug/l, to account for copper plumbing sources and increased automobile traffic from associated impervious areas. These values have little significant impact on the total load as the majority of the load is derived from surface runoff and erosion during storm events; baseflow contributions are small.

### 3.4.3 BOD Loading Rates

In this study, BOD loading rates from the land surface are simulated as a function of the surface runoff and sediment loadings, while the subsurface contributions are defined by user-specified concentrations for interflow and baseflow. For the **pervious** land surfaces, the same 'potency factor' approach described above for copper is used for BOD. For the **impervious** areas, the formulation for the surface runoff component follows the standard accumulation and washoff algorithms used in most urban runoff models; washoff during a storm event is a first-order process calculated as a function of the runoff rate, while availability is determined by daily accumulation and removal processes between events as a result of specific land use activities.

Due to limited data on BOD, model parameters were determined initially from past modeling experience in other parts of the country and were adjusted in the calibration process to produce instream concentrations in the range of the limited observed data. As shown in Table 3.9, BOD loading rates are considerably higher for impervious areas than for pervious land, up to 5 to 10 times higher. Also, rates for commercial areas are generally higher than for residential land. These differences are consistent with our past experience in modeling BOD loading rates in other studies.

## 3.5 SEDIMENT CALIBRATION

Once the sediment loading rates are calibrated to provide the expected input to the stream channel, the sediment calibration then focuses on the channel processes of deposition, scour , and transport that determine both the total sediment load and the outflow sediment concentrations to be compared with observations. Although the sediment load from the land surface is calculated in HSPF as a total input, it must be divided into sand, silt, and clay fractions for simulation of instream processes. Each sediment size fraction is simulated separately, and storages of each size are maintained for both the water column (i.e. suspended sediment) and the bed.

In this study, the **sand (non-cohesive) fraction** is transported as a power function of the average velocity in the channel reach in each timestep. This transport capacity is compared to the available inflow and storage of sand particles; the bed is scoured if there is excess capacity to be satisfied, and sand is deposited if the transport capacity is less than the available sand in the channel reach. For the **silt and clay (i.e. non-cohesive) fractions**, shear stress calculations are performed by the hydraulics (HYDR) module and are compared to user-defined critical, or threshold, values for deposition and scour for each size. When the shear stress in each timestep is greater than the critical value for scour, the bed is scoured at a user-defined erodibility rate; when the shear stress is less than the critical deposition value, the silt or clay fraction deposits at a settling rate input by the user for each size. If the calculated shear stress falls between the critical scour and deposition values, the suspended material is transported through the reach. After all scour and/or deposition fluxes have been determined, the bed and water column storages are updated and outflow concentrations and fluxes are calculated for each timestep. These simulations are performed by the SEDTRN module in HSPF, complete details of which are provided in the HSPF User Manual (Bicknell et a., 1996).

In HSPF, sediment calibration involves numerous steps in determining model parameters and appropriate adjustments needed to insure a reasonable simulation of the sediment transport and behavior of the channel system. These steps are usually as follows:

1. Divide input sediment loads into appropriate size fractions
2. Estimate initial parameter values and storages for all reaches
3. Adjust scour, deposition and transport parameters
4. Analyze sediment bed behavior and transport in each channel reach
5. Compare simulated and observed sediment concentrations where available
6. Repeat steps 1 through 5 as needed

Rarely is there sufficient observed local data to accurately calibrate all parameters for each stream reach. Consequently, model users focus the calibration on sites with observed data and review simulations in all parts of the watershed to insure that the model results are consistent with field observations, historical reports, and expected behavior from past experience. Below we discuss the use of the available data and information to estimate model parameters and to adjust them during the calibration process, and present the model results.

a. Textural data for surface soils within the watershed (SCS, 1968) were used to estimate the sand/silt/clay fractions for the soil matrix. Separate delivery ratios for each size fraction were then used to adjust the fractions to represent the textural distribution of the sediment loads reaching the stream channel. The sand fraction was typically 5% to 10% of the total sediment load to the channel, with the larger values for the open lands and steeper areas. The remaining 90% to 95% was input as silt and clay, with clay fractions being the larger values in the range of 55% to 65%.

b. Initial parameters, such as particle diameter, particle density, settling velocity, bed depth and composition, and beginning calibration parameter values were evaluated from past experience, and then adjusted based on available site data. Settling velocities were set to be consistent with data developed in District studies (Palhegyi and Driscoll, 1990; WCC, 1991). Bed composition was determined from particle distribution data from the District's Calabazas Creek Sediment Monitoring Project (SCVNSPCP, 1996; T. Cooke, WCC, personal communication, 1996). These data indicated the bed was more than 95% sand; since the model calculates scour on the entire wetted perimeter of the channel, i.e. including the channel bank slopes, the sand/silt/clay distribution was adjusted to 75/10/15 to more closely approach the surface soils and allow **bank** scour of silt and clay at reasonable flow rates.

   In the model, bed depth represents the amount of material that can be scoured from the stream reach; in effect it provides a limit so that the model will inform the user, through a warning message, when the channel has been completely scoured so that the user can make appropriate parameter changes if needed. In this study, we set the initial bed depth to 2.0 feet for the natural (i.e. non-channelized) stream segments, and .05 feet for the channelized segments (i.e. Reaches No. 5 and 6) to allow a reasonable amount of scour in the upstream natural channel and limit the scour to scattered localized deposits in the channelized sections. In addition, bed depths (and composition) were reset to these initial values at the beginning of each rainfall year (i.e., July 1) to (1) allow for sufficient bank scour at high flow rates, and (2) to provide stability in the long-term simulations for the 50-year scenario runs. We felt this was a reasonable approximation since the bed depths only serve to limit channel scour, and the banks can continue to erode at high flow rates.

c. In the initial phase of the sediment calibration the model is run with the initial parameter estimates and shear stress values are output for each stream reach. For sand particles, the coefficient and exponent of the average velocity are adjusted to control the rate of sand transport in each reach. For the silt and clay size particles, the critical shear stress parameters (one for scour and one for deposition) for each size are adjusted so that the model calculates scour during high flow events, deposition and settling during low flow periods, and transport with neither scour nor settling for moderate flow rates. During high flow periods, the amount of scour is adjusted with an erodibility factor for each reach that controls the rate of scour whenever the actual shear stress is greater than the critical shear stress value for scour.

The sediment calibration steps 4, 5, and 6 (noted above) are best discussed along with the final model results. Figure 3.10 shows the simulated and observed sediment concentrations for Calabazas Creek at Wilcox High School (District Gage No. 26 A), along with the flow simulation results in the top auxiliary plot. Table 3.11 presents the 'sediment balance' for Reaches 1, 3, and 6; the outlet of Reach 6 is the Wilcox gage.

These results demonstrate the types of analyses performed as part of the sediment calibration effort. Since sand usually comprises a small fraction of the total sediment concentration and discharge, the sand parameters are set to values to reflect this small contribution. The primary focus of the calibration is the silt and clay parameters. As noted above, the shear stress values are adjusted so that scour occurs during storm periods and deposition occurs at low flows. Once the timing of scour and deposition processes is correct, the rate of scour (i.e. erodibility factor in the model) is adjusted in an attempt to match the observed concentrations, as shown in Figure 3.10. Also, the values are set so that scour of clay occurs at lower shear values than for silt (i.e. clay scours before silt), and deposition of silt occurs at higher shear values than clay (i.e. silt deposits before clay).

As shown in Figure 3.10, the simulated concentrations cover the range of the observed values, demonstrate the direct relationship to flow levels, and are generally a good representation of the observed data. The observed data values are event mean concentrations (EMCs) for selected storms, while the simulated are average daily values from the calculated hourly values through out the day. Since not all storms were monitored, many of the simulated peak concentrations occur at times without a corresponding observed value. Also, the sediment simulations demonstrate the relationship to the flow simulation; when flow rates are accurately modeled, the sediment concentrations are usually closer to the observed, when flow is under-simulated the predicted concentrations are also under-estimated, and vice versa.

Imposing this pattern, as part of the calibration, helps to insure that the simulations are properly representing the stream sediment behavior.

While attempting to match the simulated and observed sediment concentrations, the sediment balances in each of the stream reaches must be analyzed to insure that the streambed and outflow is consistent and reasonable for the duration of the simulation. The sediment calibration was actually performed over the 10-year period, 1982-92, of which the last five years are shown in Table 3.11. The sediment balances shown in Table 3.11 include the bed depth and composition at the end of the rainfall year (e.g. 30 June 1988 for the 1988 column), and the inflow, net deposition or scour, and outflow for the entire year.

Each of the three stream reaches in Table 3.11 shows different sediment behavior reflecting the different and varying characteristics of the channel segment, but the patterns in each are reasonable and relatively stable over the five-year time period. Reaches 1 and 3 are natural channels, while Reach 6 is channelized. Reach 1 is the upper most channel segment in the model of Calabazas Creek, with the steepest slopes and highest rainfall in the watershed. All the inflow is from land surface erosion, and the channel is consistently scoured for all particles sizes over the simulation period; channel scour represents about 39% of the total outflow. The bed depth reflects the channel scour and shows up to 0.74 feet scoured in 1992.

Reach 3 is in the middle of the watershed, with relatively mild slopes and moderate rainfall i.e. in the midrange of rainfall within the watershed. Sand is scoured in some years (1988-90) and deposited in others (1991-92); the highest rainfall years also have the highest inflow of sand from erosion that subsequently deposits in the channel. Silt and clay are scoured every year, and channel scour represents about 18% of the total outflow; in this case the inflow includes both local erosion and contributions from the upstream reaches. The bed depth shows some scour in each year, but at lesser amounts than in Reach 1.

Reach 6 is channelized, and it is the final reach in the model of the watershed, with its outlet at District Gage No. 26A at Wilcox High School. Because it is concrete-lined, its bed depth is minimal and its composition is primarily sand. Some small amount of scour does occur from scattered, localized deposits, but channel scour represents less than .2% of the total outflow. Sand appears to be deposited primarily upstream of the channelized sections, as indicated by the observed data on bed samples being more than 95% sand (SCVNSPCP, 1996).

The outflow sediment loads from Reach 6 in Table 3.11 represent the simulated annual sediment load from Calabazas Creek at the Wilcox gage. There are no observed data to confirm these annual values since all storm events in any year were not monitored. However, the simulated average annual value of 4126 tons/year for the five-year period is consistent with the estimate of 3843 tons/year based on the 1988-95 monitoring data, while the simulated values for 1988 and 1989 of 2589 and 1530 tons/year are higher than the 1477 tons/year estimate (WCC, 1996a, Table 4-2). Since these estimates are based on a few samples in each year and a 10-year average flow, while the simulated values are derived from values for a complete timeseries, we feel the general agreement is good. Based on both the

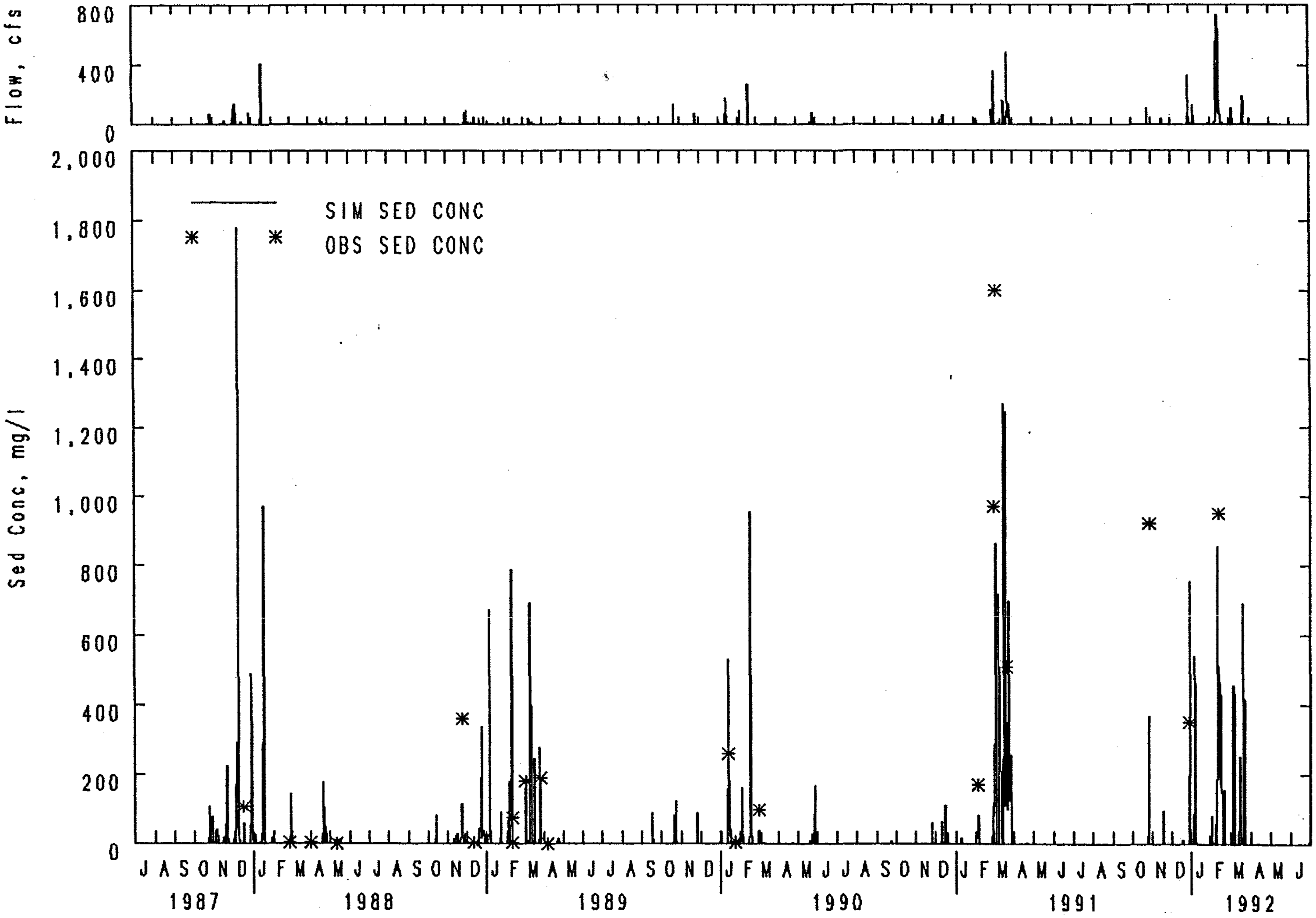

Figure 3.10 Simulated and Observed Sediment Concentration and Observed Flow at Reach 6, Calabazas Creek at Wilcox High School

**Table 3.11 Sediment Balances for REACH 1, REACH 3, and REACH 6 - Calabazas Creek**

| **REACH 1** | 1988 | 1989 | 1990 | 1991 | 1992 | SUM/AVER |
|---|---|---|---|---|---|---|
| Bed Depth(ft) | 1.920 | 1.900 | 1.900 | 1.510 | 1.260 | 1.698 |
| Bed Comp(t) | | | | | | |
| Sand | 4000. | 3930. | 3919. | 3610. | 3341. | 3760. |
| Silt | 484.7 | 486.2 | 487.4 | 292.3 | 117.4 | 373.6 |
| Clay | 631.7 | 646.0 | 654.2 | 222.7 | 30.25 | 437.0 |
| Total | 5117. | 5062. | 5061. | 4125. | 3489. | 4571. |
| Inflow(t) | | | | | | |
| Sand | 90.59 | 79.11 | 66.72 | 135.1 | 175.9 | 109.5 |
| Silt | 242.1 | 211.7 | 182.9 | 364.1 | 479.8 | 296.1 |
| Clay | 600.6 | 525.3 | 447.9 | 899.4 | 1177. | 730.0 |
| Total | 933.2 | 816.1 | 697.6 | 1399. | 1833. | 1136. |
| Dep/Scour(t) | | | | | | |
| Sand | -4.281 | -26.42 | -36.80 | -346.1 | -614.8 | -205.7 |
| Silt | -49.25 | -43.36 | -42.10 | -237.2 | -412.1 | -156.8 |
| Clay | -169.2 | -148.3 | -140.1 | -571.6 | -764.1 | -358.7 |
| Total | -222.8 | -218.1 | -219.0 | -1155. | -1791. | -721.2 |
| Outflow(t) | | | | | | |
| Sand | 94.87 | 105.5 | 103.5 | 481.2 | 790.7 | 315.2 |
| Silt | 291.3 | 255.0 | 225.0 | 601.3 | 891.9 | 452.9 |
| Clay | 769.8 | 673.6 | 588.1 | 1471. | 1941. | 1089. |
| Total | 1156. | 1034. | 916.6 | 2554. | 3624. | 1857. |
| **REACH 3** | | | | | | |
| Bed Depth(ft) | 1.920 | 1.940 | 1.920 | 1.790 | 1.560 | 1.826 |
| Bed Comp(t) | | | | | | |
| Sand | 6606. | 6538. | 6531. | 6608. | 6582. | 6573. |
| Silt | 828.9 | 844.9 | 830.7 | 703.0 | 390.6 | 719.6 |
| Clay | 1032. | 1149. | 1102. | 673.6 | 137.2 | 818.8 |
| Total | 8466. | 8532. | 8463. | 7984. | 7110. | 8111. |
| Inflow(t) | | | | | | |
| Sand | 53.20 | 38.32 | 40.16 | 223.1 | 446.9 | 160.3 |
| Silt | 494.1 | 309.9 | 300.2 | 1135. | 1623. | 772.4 |
| Clay | 1243. | 792.6 | 746.8 | 2792. | 3654. | 1846. |
| Total | 1790. | 1141. | 1087. | 4150. | 5723. | 2778. |
| Dep/Scour(t) | | | | | | |
| Sand | -9.498 | -3.439 | -10.73 | 66.17 | 40.48 | 16.60 |
| Silt | -53.17 | -27.26 | -41.53 | -169.2 | -481.6 | -154.6 |
| Clay | -291.5 | -159.6 | -206.4 | -634.7 | -1171. | -492.6 |
| Total | -354.2 | -190.3 | -258.6 | -737.8 | -1612. | -630.6 |
| Outflow(t) | | | | | | |
| Sand | 62.70 | 41.76 | 50.89 | 156.9 | 406.4 | 143.7 |
| Silt | 547.2 | 337.2 | 341.7 | 1304. | 2104. | 926.8 |
| Clay | 1534. | 952.2 | 953.2 | 3427. | 4825. | 2338. |
| Total | 2144. | 1331. | 1346. | 4888. | 7336. | 3409. |
| **REACH 6** | | | | | | |
| Bed Depth(ft) | 0.5000E-01 | 0.5000E-01 | 0.5000E-01 | 0.5000E-01 | 0.5000E-01 | 0.5000E-01 |
| Bed Comp(t) | | | | | | |
| Sand | 233.8 | 232.3 | 232.1 | 230.0 | 229.2 | 231.5 |
| Silt | 0.8113E-02 | 0.5130E-02 | 0.6920E-02 | 0.1875E-03 | 0.2062E-02 | 0.4483E-02 |
| Clay | 0.1676E-03 | 0.1583E-02 | 0.1816E-02 | 0.2081E-03 | 0.6179E-03 | 0.8785E-03 |
| Total | 233.8 | 232.3 | 232.1 | 230.0 | 229.2 | 231.5 |
| Inflow(t) | | | | | | |
| Sand | 5.580 | 3.396 | 6.054 | 11.72 | 30.54 | 11.46 |
| Silt | 668.4 | 393.1 | 506.2 | 1557. | 2674. | 1160. |
| Clay | 1909. | 1129. | 1351. | 4143. | 6211. | 2949. |
| Total | 2583. | 1525. | 1864. | 5712. | 8915. | 4120. |
| Dep/Scour(t) | | | | | | |
| Sand | -1.080 | -0.3629 | -0.5720 | -2.732 | -3.517 | -1.653 |
| Silt | -2.389 | -2.372 | -2.370 | -2.377 | -2.375 | -2.377 |
| Clay | -2.397 | -2.375 | -2.375 | -2.377 | -2.376 | -2.380 |
| Total | -5.866 | -5.110 | -5.317 | -7.486 | -8.268 | -6.409 |
| Outflow(t) | | | | | | |
| Sand | 6.660 | 3.759 | 6.626 | 14.45 | 34.06 | 13.11 |
| Silt | 670.8 | 395.5 | 508.6 | 1559. | 2677. | 1162. |
| Clay | 1912. | 1131. | 1354. | 4146. | 6213. | 2951. |
| Total | 2589. | 1530. | 1869. | 5719. | 8924. | 4126. |

concentration and load comparisons, we feel the simulation is a reasonable representation of the sediment generation, transport, and loads for the Calabazas Creek watershed.

## 3.6 WATER QUALITY CALIBRATION

Using the nonpoint loadings calibrated as discussed in Section 3.4, the water quality calibration was focussed on the instream simulation of copper, DO, and BOD. As noted earlier, water temperature is a required input for sediment and the DO/BOD simulation; this was satisfied by using mean monthly water temperature values for selected streams in the region with water temperature data.

Copper was elected as the primary metal of concern based on a recent review by Woodward-Clyde Consultants (1996b), and sediment was selected because it is the primary transport medium for copper, in addition to being a pollutant itself. BOD was selected to represent non-conservative pollutants that undergo losses through both settling to the channel bed and transformation/decay mechanisms. Ideally, nutrients (e.g. nitrate, ammonia, phosphate, total nitrogen, total phosphorus) would also be simulated due to their impact on water quality, but project resources and lack of available data limited the scope of the modeling effort. BOD was considered a surrogate for the likely range of impacts of DBs on nutrient loads.

Parameter estimation for the copper simulation involved estimating initial bed concentrations; partition coefficients for sand, silt, and clay; and transfer/exchange rates for sorption in the water column and between the water column and the bed. Initial bed copper concentrations for each stream reach were obtained directly from the bed samples collected by the Calabazas Creek Sediment Monitoring Pilot Project as reported by the District (SCVNSPCP, 1996). In line with the sediment procedures noted above, we reset the initial bed copper concentrations to these initial values on 1 July of each year to allow bank scour sources and stability in the long-term simulations.

The initial value for a partition coefficient was obtained from the Discrete Monitoring Special Study reported by the SCVNSPCP in 1993 (SCVNSPCP, 1993); that value of 29,079 l/kg was used initially for the silt and clay fractions, and the sand value was assumed to be about 1/3 of that value, or 10,000 l/kg. These values were subsequently adjusted in the calibration (as discussed below).

The transfer, or exchange, rates for sorption between the suspended sediment and dissolved copper, and between the water column and the bed for copper were initially obtained from past experience with pesticide modeling efforts using HSPF on agricultural watersheds in Iowa (Donigian et al., 1993; Donigian et al., 1983). Since pesticides are highly sorbed to soil and sediment particles, these rates were judged to be a reasonable starting point. Both the adsorption process of copper onto suspended sediment particle, and the transfer/exchange between the bed and the water column, are represented as kinetic first-order processes. The rates for suspended sediment represent how quickly the dissolved copper and the sorbed copper approach an equilibrium state defined by the partition coefficient; the bed rates represent how quickly the copper in the bed and dissolved in the water column approach the equilibrium state. The initial values were adjusted during the calibration.

Initial parameterization for both DO and BOD was based on parameter values obtained from previous studies. These included reaeration formulas and rates, and decay and settling rates for BOD. No observed DO data, and only nine BOD data points, were available for calibration. The BOD decay and settling rates were adjusted during calibration based on comparison with the observed data, and the rates were maintained within expected ranges tabulated by Bowie et al (1985). Neither nutrient dynamics nor algal impacts on DO and BOD were considered in these simulations, although these capabilities are present in HSPF, due to the lack of observed data. As noted earlier, the BOD simulation was included to investigate and demonstrate the potential impacts of detention on non-conservative pollutants that degrade, settle, and may be consumed by other processes.

Figure 3.11 shows the simulated and observed **Dissolved Copper** concentrations, while Figure 3.12 shows the corresponding **Total Copper** concentrations, at District Gage No. 26A at Wilcox High School, for the calibration period of 1987 to 1992. In Figure 3.13, the simulated DO values are shown in the top diagram, while the simulated and observed BOD values are in the lower diagram. These results demonstrate a good simulation of the observed concentration data for essentially all constituents. The response to storm events is evident as shown by the auxiliary flow plots in the top curves of Figures 3.11 and 3.12. Although individual observed data points do not always match with the simulated values, the model does a good job of representing both the range and temporal pattern of the observations.

In reviewing these results, we provide the following comments:

a. The dissolved copper concentrations (Figure 3.11) show an under-simulation in 1988-89, but much closer agreement for the latter years. It should be noted that the flow values for the 1988-89 winter were generally over-simulated, which would lead to the lower than observed concentrations. Also, it was an extremely dry year, and there were some obvious problems in the consistency between the rainfall and flow data.

b. Although the peak dissolved concentrations show an increase over the five-year period, this is apparently an artifact of the increase in peak flow rates and associated increase in copper loads. There were no apparent increasing trends in the 50-year runs.

c. The peak dissolved concentrations are often during small to moderate storm events, and the simulation shows decreasing concentrations during the larger events.

d. The Total Copper concentration is dominated by the adsorbed fraction which shows a more direct relationship with flow levels. As shown in Figure 3.12, the range and pattern of the observations are well represented by the simulated values. In many cases, the simulated peaks occur when specific storms were not monitored.

e. The drop in concentrations in May and June, most obvious for dissolved copper, BOD and DO is coincident with the decrease in flow to almost negligible levels. In many

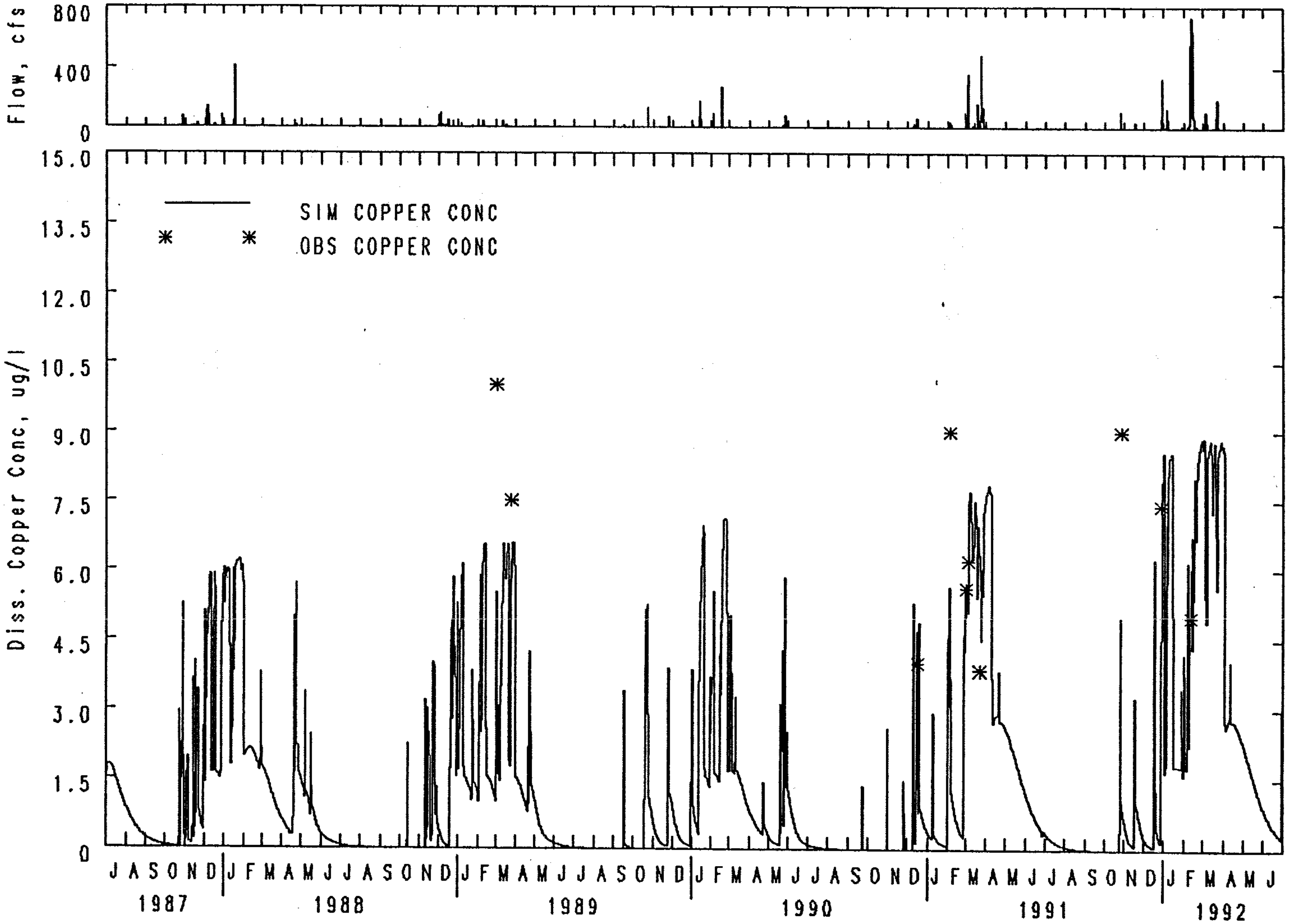

Figure 3.11 Simulated and Observed Dissolved Copper Concentration at Reach 6
Calabazas Creek at Wilcox High School

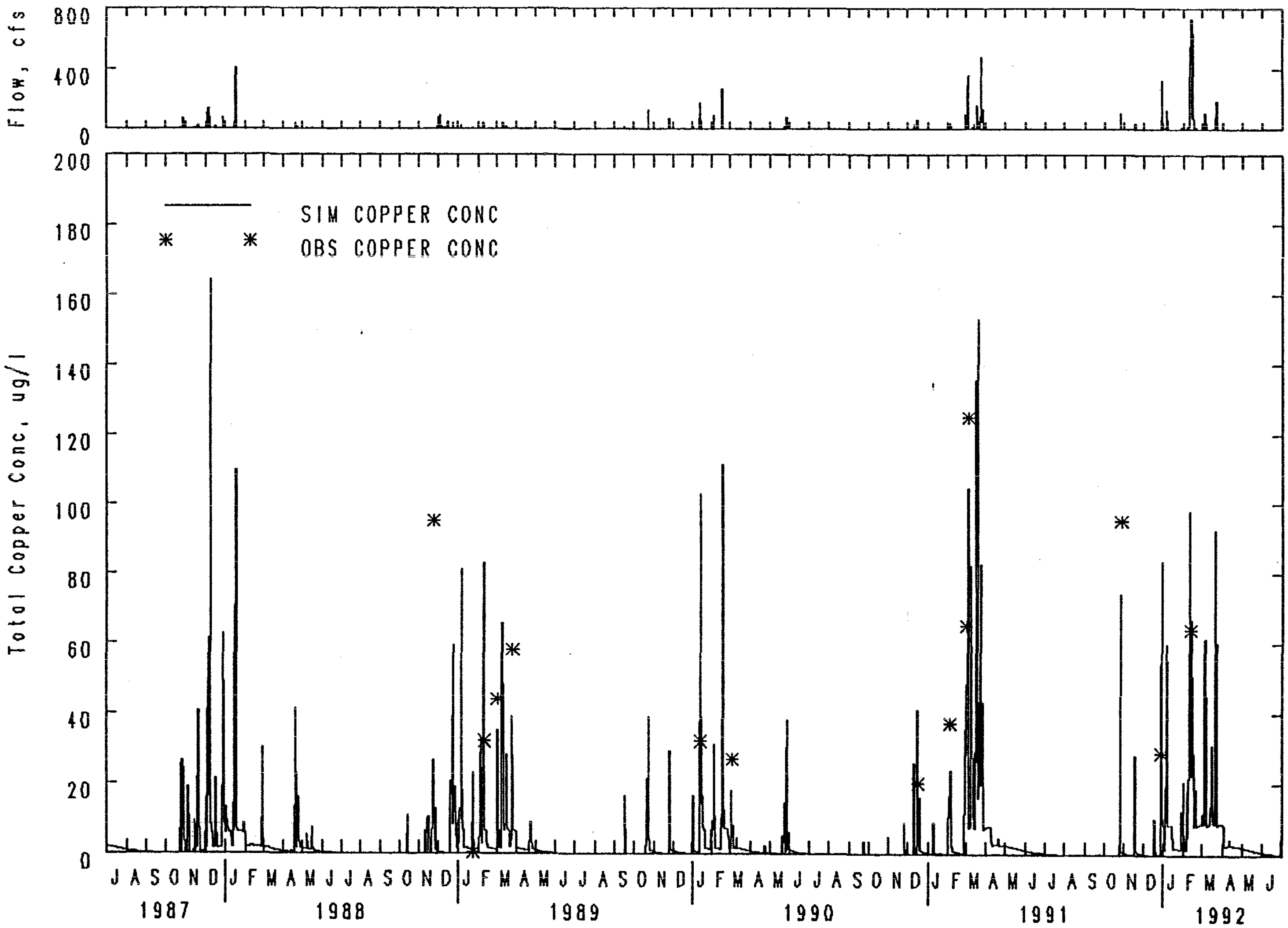

Figure 3.12 Simulated and Observed Total Copper Concentration at Reach 6
Calabazas Creek at Wilcox High School

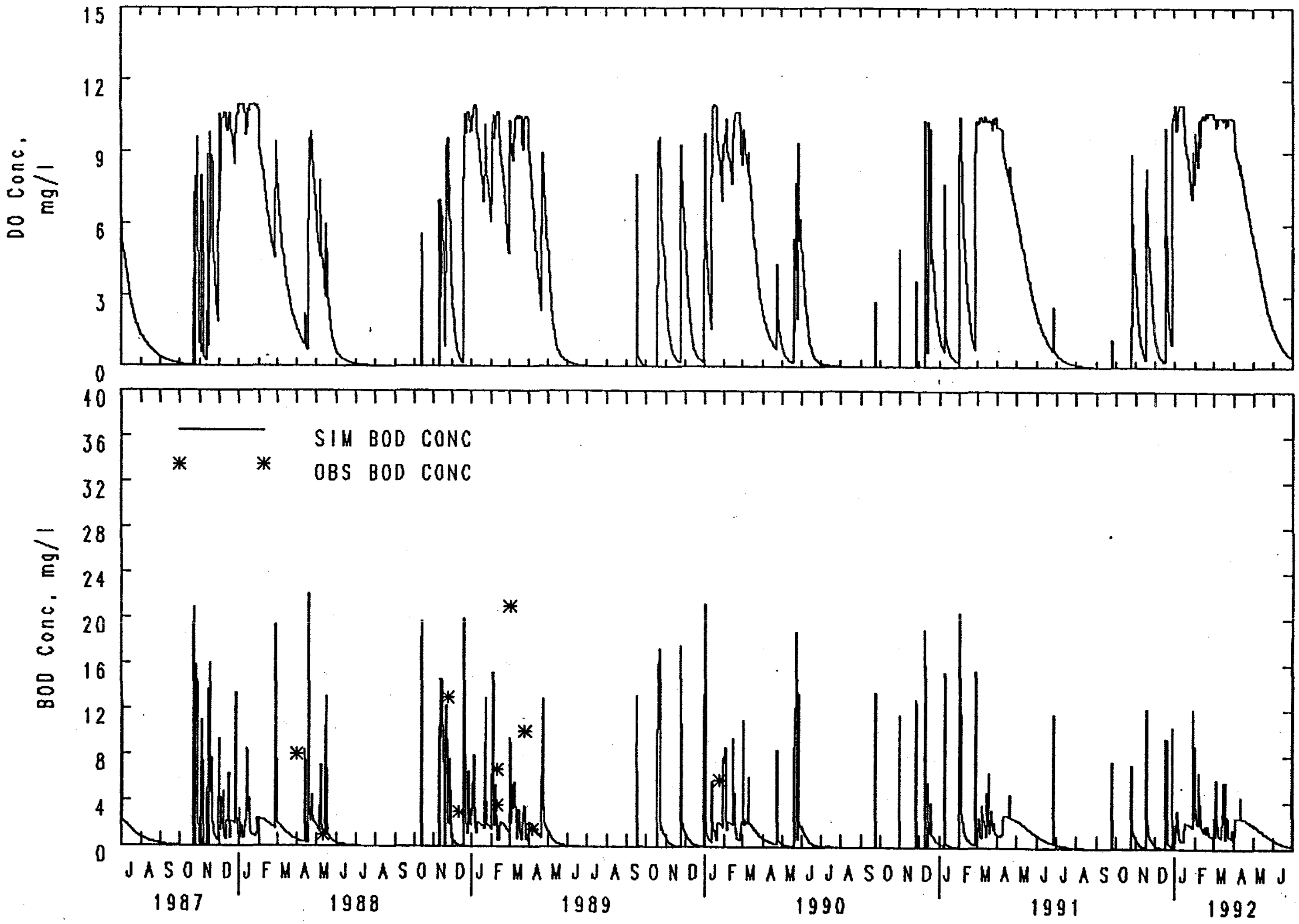

Figure 3.13 Simulated DO and Simulated and Observed BOD Concentration at Reach 6, Calabazas Creek at Wilcox High School

parts of Calabazas Creek, the stream is ephemeral and goes completed dry during summer months. To avoid mathematical problems with extremely low flow rates (and associated high concentrations), a constant flow source of 0.2 cfs was input to the stream in the uppermost reach. There is evidence to support this approach in that lawn irrigation and small point flows contribute to the stream throughout the summer.

f. The BOD simulation in Figure 3.13 shows a good representation of the limited amount of observed data available. The BOD peaks associated with storm peaks are characteristic of small urban watersheds.

Tables 3.12 and 3.13 show copper and BOD balances for Reach 3 and Reach 6 of Calabazas Creek, analogous to the sediment balances discussed in Section 3.5. For copper, values for bed storage, inflow, deposition/scour, and outflow are analogous to the correspond values in the sediment balances discussed earlier. However, an additional set of values is provided for adsorption and desorption onto suspended and bed sediments in the reach; desorption is represented by a negative value. For BOD, sinking or settling, and decay are the only losses included in these simulations, and their values are shown at the bottom of the tables.

As noted earlier, Reach 3 is a natural channel while Reach 6 is concrete-lined throughout its length and it ends at District Gage 26A at Wilcox High School. With these differences in mind, the values in these tables show the following:

a. Bed storages of copper are significantly greater in Reach 3. Although the reaches differ in both length and bed copper concentrations, the primary difference is the availability of a significant sediment bed; Reach 3 has an assumed 2 foot bed while, Reach 6 has only scattered deposits with an assumed depth of 0.05 feet.

b. Inflows of copper and BOD differ because of the differing size of the local tributary drainage areas; Reach 3 is in the middle of the watershed while Reach 6 is at the outlet of the area simulated in this study.

c. As might be expected, the impact of adsorption/desorption and scour is much greater in Reach 3. In both reaches, copper desorbs from the suspended sediments, and from the bed sand in Reach 3; however, the amounts are small, almost negligible, in Reach 6. In Reach 3, copper desorbs from the bed sand but adsorbs to the bed silt and clay, which serves to partly offset the total contribution from the bed. This results from the bed being primarily sand and from the lower partition coefficient for the sand particles.

d. In Reach 3, the gain in copper from bed desorption and scour is about 14% of the inflow to the reach; whereas, in Reach 6 the total gain is insignificant. Also, in Reach 3 copper is scoured except for the sand fraction, whereas in Reach 6 copper is primarily deposited but in very small amounts.

e. The interaction with the bed, as described in c (above), leads to an increase in the dissolved fraction in the reach, comparing the inflow load to the outflow load; the increase is about a factor of two. However, due to the high partition coefficients for copper, the dissolved fraction is still a small portion of the total load, about 5% or less.

f. For BOD, the loss mechanisms of settling and decay account for about 5% loss of the inflow load in Reach 3, and 2% in Reach 6. These losses are small due to the short travel times; the Reach 3 loss is higher due its length being almost twice as long as for Reach 6.

g. The mean copper load from Reach 6 is 1177 lbs/year for the five-year period, whereas WCC's estimated mean load is 811 lbs/year (WCC, 1996a, Table 4-2) using a 10-year mean runoff and a mean concentration of 52 ug/l from the EMCs of the samples in the 1988-95 monitoring. Since the model estimate is based on copper concentrations and flows for all storm events, we feel the two estimates are reasonably consistent.

In conclusion, the water quality simulations are clearly within the range of the observed data and provide a good representation of the dynamic behavior of sediment, copper, and BOD concentrations and loads from Calabazas Creek. A number of additional improvements in the simulations could be implemented, including a finer segmentation of the land segments and channel reaches, use of more rain gages and a smaller simulation timestep, consideration of lawn watering and point sources, and additional calibration for both flow and water quality for the most recent time period with more extensive water quality data (i.e. 1992-96). However, the current simulations are sufficiently close to observations to provide a sound and viable basis as a baseline for evaluating potential impacts of alternative detention scenarios.

## Table 3.12 Copper and BOD balance for REACH 3 - Calabazas Creek

| | 1988 | 1989 | 1990 | 1991 | 1992 | SUM/AVER |
|---|---|---|---|---|---|---|
| **COPPER (lbs)** | | | | | | |
| Bed Stor.(lbs) | | | | | | |
| Sand | 478.2 | 445.0 | 424.3 | 401.8 | 368.9 | 423.6 |
| Silt | 144.0 | 145.2 | 140.0 | 114.7 | 57.03 | 120.2 |
| Clay | 179.2 | 177.9 | 162.4 | 96.85 | 16.84 | 126.6 |
| Total | 801.4 | 768.1 | 726.6 | 613.4 | 442.8 | 670.5 |
| Inflow(lbs) | | | | | | |
| Dissolved | 11.45 | 9.032 | 7.513 | 18.01 | 23.69 | 13.94 |
| Sand | 12.38 | 6.970 | 8.674 | 26.98 | 49.71 | 20.94 |
| Silt | 168.5 | 99.00 | 106.4 | 322.0 | 467.5 | 232.7 |
| Clay | 304.1 | 180.4 | 192.1 | 580.8 | 806.4 | 412.8 |
| Total | 496.5 | 295.4 | 314.8 | 947.8 | 1347. | 680.3 |
| Ad/Desorp(lbs) | | | | | | |
| Sus.Sand | -0.1995 | -0.1158 | -0.1580 | -0.2587 | -0.4612 | -0.2386 |
| Sus.Silt | -2.364 | -1.485 | -1.904 | -4.126 | -7.130 | -3.402 |
| Sus.Clay | -3.243 | -1.765 | -2.757 | -4.161 | -7.717 | -3.929 |
| Bed Sand | -39.04 | -33.39 | -20.46 | -30.08 | -38.90 | -32.37 |
| Bed Silt | 13.13 | 5.614 | 1.757 | 1.934 | 7.280 | 5.943 |
| Bed Clay | 18.02 | 21.75 | 13.64 | 19.02 | 23.53 | 19.19 |
| Total | -13.69 | -9.396 | -9.880 | -17.67 | -23.40 | -14.81 |
| Dep/Scour(lbs) | | | | | | |
| Sand | 0.2327 | 0.2035 | -0.3006 | 7.652 | 6.001 | 2.758 |
| Silt | -8.719 | -4.507 | -6.894 | -27.20 | -65.00 | -22.46 |
| Clay | -48.29 | -22.98 | -29.23 | -84.53 | -103.5 | -57.71 |
| Total | -56.78 | -27.28 | -36.43 | -104.1 | -162.5 | -77.42 |
| Outflow(lbs) | | | | | | |
| Dissolved | 25.14 | 18.43 | 17.39 | 35.68 | 47.08 | 28.74 |
| Sand | 11.95 | 6.651 | 8.816 | 19.06 | 43.25 | 17.95 |
| Silt | 174.9 | 102.0 | 111.4 | 345.1 | 525.4 | 251.8 |
| Clay | 349.2 | 201.6 | 218.6 | 661.2 | 902.2 | 466.6 |
| Total | 561.1 | 328.7 | 356.2 | 1061. | 1518. | 765.0 |
| **BOD (lbs)** | | | | | | |
| Inflow | 55730. | 44200. | 47390. | 66850. | 84950. | 59820. |
| Gains/Losses | | | | | | |
| Sink | -2368. | -2284. | -2511. | -2646. | -2613. | -2484. |
| Decay | -252.5 | -215.3 | -243.9 | -281.5 | -331.6 | -265.0 |
| Total | -2621. | -2500. | -2755. | -2928. | -2945. | -2750. |
| Outflow | 53110. | 41700. | 44630. | 63920. | 82000. | 57070. |

# Table 3.13 Copper and BOD balance for REACH 6 - Calabazas Creek

| | 1988 | 1989 | 1990 | 1991 | 1992 | SUM/AVER |
|---|---|---|---|---|---|---|
| **COPPER (lbs)** | | | | | | |
| Bed Stor.(lbs) | | | | | | |
| Sand | 13.74 | 14.14 | 14.58 | 14.97 | 17.11 | 14.91 |
| Silt | 0.5770E-02 | 0.3245E-02 | 0.3064E-02 | 0.1011E-03 | 0.1067E-02 | 0.2649E-02 |
| Clay | 0.8478E-04 | 0.8931E-03 | 0.6066E-03 | 0.1090E-03 | 0.3070E-03 | 0.4001E-03 |
| Total | 13.75 | 14.14 | 14.58 | 14.97 | 17.11 | 14.91 |
| Inflow(lbs) | | | | | | |
| Dissolved | 44.49 | 31.88 | 37.07 | 70.42 | 102.3 | 57.23 |
| Sand | 2.251 | 1.326 | 3.115 | 3.975 | 10.32 | 4.197 |
| Silt | 252.9 | 134.0 | 226.5 | 490.3 | 836.4 | 388.0 |
| Clay | 514.9 | 270.9 | 434.1 | 956.0 | 1465. | 728.2 |
| Total | 814.5 | 438.2 | 700.8 | 1521. | 2414. | 1178. |
| Ad/Desorp(lbs) | | | | | | |
| Sus.Sand | -0.1535E-01 | -0.7886E-02 | -0.2495E-01 | -0.2919E-01 | -0.5095E-01 | -0.2567E-01 |
| Sus.Silt | -1.373 | -0.7975 | -1.339 | -2.132 | -3.101 | -1.749 |
| Sus.Clay | -1.508 | -0.7371 | -1.657 | -1.941 | -3.237 | -1.816 |
| Bed Sand | 0.1135 | -0.1012 | 0.1912 | 0.2318 | 0.2592 | 0.1389 |
| Bed Silt | -0.6722E-02 | 0.1354E-01 | 0.2692E-03 | 0.1054E-01 | 0.3296E-03 | 0.3591E-02 |
| Bed Clay | -0.9234E-03 | 0.8206E-03 | -0.1177E-04 | 0.2491E-02 | 0.4212E-03 | 0.5595E-03 |
| Total | -2.790 | -1.629 | -2.830 | -3.858 | -6.130 | -3.447 |
| Dep/Scour(lbs) | | | | | | |
| Sand | 0.4460 | 0.5015 | 0.2452 | 0.1579 | 1.885 | 0.6471 |
| Silt | 0.1870 | 0.8669E-01 | 0.4103E-01 | 0.1814E-01 | 0.1117 | 0.8891E-01 |
| Clay | -0.7046 | 0.1318E-01 | 0.7218E-02 | 0.3758E-02 | 0.2936E-02 | -0.1355 |
| Total | -0.7161E-01 | 0.6014 | 0.2935 | 0.1798 | 2.000 | 0.6006 |
| Outflow(lbs) | | | | | | |
| Dissolved | 47.28 | 33.51 | 39.90 | 74.28 | 108.4 | 60.67 |
| Sand | 1.790 | 0.8163 | 2.845 | 3.788 | 8.379 | 3.524 |
| Silt | 251.3 | 133.1 | 225.1 | 488.1 | 833.2 | 386.2 |
| Clay | 514.1 | 270.2 | 432.4 | 954.0 | 1462. | 726.5 |
| Total | 814.5 | 437.6 | 700.3 | 1520. | 2412. | 1177. |
| **BOD (lbs)** | | | | | | |
| Inflow | 79520. | 64390. | 75210. | 86760. | 118600. | 84900. |
| Gains/Losses | | | | | | |
| Sink | -1516. | -1570. | -1335. | -1414. | -1322. | -1431. |
| Decay | -169.8 | -149.6 | -168.5 | -170.7 | -211.9 | -174.1 |
| Total | -1686. | -1720. | -1503. | -1585. | -1534. | -1606. |
| Outflow | 77830. | 62670. | 73710. | 85180. | 117100. | 83300. |

# SECTION 4.0

# SCENARIO DEVELOPMENT, ASSUMPTIONS, AND SIMULATION RESULTS

## 4.1 OVERVIEW

In order to evaluate the potential impacts of detention on both flood control and water quality, a series of model scenarios were developed and simulated. In conjunction with District staff, three alternative scenarios were defined. First, a scenario of detention basins designed solely for flood control in Calabazas Creek was simulated. Then, three additional scenarios were developed to superimpose changes in the detention basins to increase detention time for nonpoint source load attenuation and water quality improvement, and then focus on drainage from impervious areas which are major sources. A baseline condition, without detention, was also simulated in order to have a framework, or basis, for comparing potential impacts of each modeled scenario. Thus, the following five conditions were implemented within the model and simulated:

- Baseline Conditions (**BC**)
- Flood Control Scenario (**FC**)
- Flood Control plus Permanent Water Quality Pool (**WQP**)
- Flood Control plus Permanent Water Quality Pool and Extended Detention (**WQP/ED**)
- Flood Control plus Permanent Water Quality Pool and Extended Detention draining primarily impervious areas (**WQP/EDI**)

For each scenario, 50-year simulations were performed with the HSPF model of Calabazas Creek, and flows, water quality concentrations, and loads were output and analyzed at both the Rainbow and Wilcox High School gage locations. In addition, for each detention basin simulated, input and output flows and loads were analyzed to assess the flow reductions and removal efficiencies implemented in the simulation. This section describes the basis for developing the scenarios, representing the detention basins, their insertion into the model, the meteorologic database for the 50-year simulations, and the comparative results of all scenarios. Note that the **BOLD** designations (i.e. **BC**, **FC**, **WQP**, **WQP/ED**,**WQP/EDI** ) above will be used in our discussions of these scenarios.

## 4.2 SCENARIO DEVELOPMENT

As noted above, the scenarios were developed to represent a sequential series of alternative changes in the model representation of the watershed. First, a Baseline Condition was defined so that all scenario impacts could be compared to a defined standard condition, and so that marginal impacts between scenarios could also be evaluated. For each of the four alternative scenarios (i.e. **FC, WQP, WQP/ED, WQP/EDI**), a detention basin was inserted into each model segment to **drain 20% of the segment area** and then discharge through its outlet to the stream channel in that segment. In the first three scenarios, the detention basin drainage area was limited to the residential and commercial land within the segment in the same relative proportions as for the baseline condition; no open land was included in the detention basin drainage area on the assumption that the basins were designed to offset urbanization impacts. In the final scenario, **WQP/EDI,** the drainage areas were adjusted to include all the available impervious area within a model segment. Table 4.1 lists the model segment and detention basin drainage areas along with selected basin characteristics. The detention basins (DBs) are numbered to correspond to the model segment where they are located, so DB1 is in Model Segment No. 1, DB2 is in Model Segment No. 2, etc.

**Table 4.1 MODEL SEGMENT AREAS AND DETENTION BASIN CHARACTERISTICS**

| | | | Detention Basins | | | |
|---|---|---|---|---|---|---|
| | DB1 | DB2 | DB3 | DB4 | DB5 | DB6 |
| DB Drainage Area (ac) | 363.5 | 263.7 | 677.1 | 203.5 | 277.8 | 60.2 |
| Model Segment Area (ac) | 1817.6 | 1318.4 | 3385.5 | 1017.6 | 1388.8 | 300.8 |
| *Surface Area (ac) | 4.3 | 3.1 | 8.0 | 2.4 | 3.3 | 0.7 |
| *Capacity without WQ pool (ac.ft.) | 19.1 | 13.9 | 35.5 | 10.7 | 14.6 | 3.2 |
| *Capacity with WQ Pool (ac.ft.) | 26.7 | 19.4 | 49.8 | 15.0 | 20.4 | 4.4 |

* - at spillway crest

### 4.2.1 50-Year Database for Simulation

A 50-year meteorologic data base was established so that long-term model runs could be executed to define reasonable mean and frequency statistics for both flow and water quality variables. This required continuous timeseries of hourly precipitation and daily evaporation for the entire 50-year period from 1942 to 1992. The long-term hourly precipitation from the National Weather Service (NWS) gage for San Jose (SCVWD Station ID 86) was selected as the primary dataset because it has hourly coverage for most of the period 1908-1984, with four periods of daily coverage ranging from one month to three years in length, plus daily coverage from 1984-1996. The daily periods, including the 1984-92 time span, were filled using the NCDC hourly data set for San Jose (Station ID 7821) which is located at the same general site. The final hourly data set covers the period from 1 January 1908 to 30 June 1996. Due to the large variation in rainfall across the watershed, this rainfall timeseries for each model segment was adjusted by the ratio of the mean segment rainfall to the mean rainfall at the San Jose stations. These adjustment factors varied from 1.07 at the bottom of the watershed to 2.5 at the top.

The extended 50-year monthly evaporation data set was created from the original data set for the Los Alamitos Recharge Facility used in the simulation. Monthly averages were computed over the period from 1959 to 1995 (the last complete water year), and these values were used as the monthly values to extend the data set back from 1958 to 1942.

### 4.2.2 Detention Basin Simulation

In order to model the addition of a detention basin within an HSPF model segment, the FTABLE for the basin must be developed, the segment drainage area must be reduced by the amount of land draining to the basin, the inflow from the drainage area must be directed to the basin, and the discharge from the basin must be directed back to the stream channel. All these adjustments are represented by changes to the model input used for the Baseline Condition.

As opposed to designing specific detention basins for specific sites within each model segment, we obtained the design information for a typical real basin from the District and then used the information to develop an appropriate FTABLE specifying the stage, volume, surface area, and discharge relationship. Table 4.2 shows this information for the detention basin designed for an 800 acre drainage area near Morgan Hill. The shaded values in Table 4.2 are values obtained directly from District information, and the remaining values were calculated through interpolation and extrapolation of the District's values in order to complete the FTABLE. The detention time in the final column in Table 4.1 was calculated as follows:

$$\text{Detention time, hours} = (\text{Vol}/Q*1.98)*24$$

where Q = basin outflow, cfs
Vol = basin storage volume, ac. ft.

## Table 4.2 Calculation of Stage-Volume-Discharge (FTABLE) Relations for a 'TYPICAL' Detention Basin

| Stage ft | Elev. ft | Volume ac-ft | Qout cfs | Surface Area ac | Detention Time hours | Comment |
|---|---|---|---|---|---|---|
| 0.00 | 354 | 0.00 | 0.00 | 8.4 | | Invert Elevation |
| 1.00 | 355 | 8.40 | 7.88 | 8.6 | 12.9 | |
| 1.06 | 355.06 | 9.60 | 9.00 | 8.6 | 12.9 | |
| 1.42 | 355.42 | 12.36 | 15.00 | 8.7 | 10.0 | |
| 2.00 | 356 | 16.80 | 18.59 | 8.8 | 11.0 | |
| 2.36 | 356.36 | 19.79 | 21.00 | 8.9 | 11.4 | |
| 3.00 | 357 | 25.10 | 22.98 | 9.0 | 13.2 | |
| 4.00 | 358 | 33.50 | 26.10 | 9.2 | 15.6 | |
| 4.76 | 358.76 | 39.96 | 28.50 | 9.3 | 17.0 | |
| 5.00 | 359 | 42.00 | 31.66 | 9.5 | 16.1 | Spillway crest |
| 5.10 | 359.1 | 42.94 | 47.43 | 9.5 | 11.0 | |
| 5.20 | 359.2 | 43.88 | 76.27 | 9.5 | 7.0 | |
| 5.50 | 359.5 | 46.70 | 207.99 | 9.6 | 2.7 | |
| 5.70 | 359.7 | 48.58 | 323.76 | 9.7 | 1.8 | |
| 6.00 | 360 | 51.40 | 530.41 | 9.8 | 1.2 | |

Detention time, hours = (Vol/Q*1.98)*24; Vol in ac ft, and Q in cfs

Note: 1. Data are based on West Little Llagas Cr. SHALLOW Pond Design; Drainage area = 800 acres

2. Shaded values were obtained from the District while the other numbers were calculated by interpolation and extrapolation.

In reality, these basins could represent an actual basin sited within the model segment since the basin characteristics are derived from an actual District design (see Section 4.2.2 below), or the aggregate impact of a number of smaller basins with the same total drainage area, volume capacity, discharge, etc.

To determine the FTABLES for each detention basin within each model segment, we adjusted the discharge, volume and surface area values in Table 4.2 by the ratio of the basin drainage area to the 800 acre drainage area of the 'typical' basin. Table 4.3 shows the FTABLES used for the three scenarios for the detention basin in Model Segment No. 3, which we designate as Detention Basin No. 3 (DB3); the FTABLES for all the detention basins are included in Appendix B.

As noted above, the Flood Control FTABLE in Table 4.3 was derived from the one in Table 4.2 by multiplying the volume, discharge, and surface areas in Table 4.2 by the ratio of the drainage areas, i.e. 677/800 = 0.85. Comparing the two FTABLES, we can see that the uniform changes in volume and discharge produced identical detention times for both basins. Since the detention time changes with depth, we selected the detention time at a mean depth of 3 feet to characterize and compare the alternatives. For the FC scenario, the mean detention time was 13.2 hours, with a range of 10 to 17 hours from invert to spillway crest. Although these detention values are for DB3 in Table 4.3, the detention times are the same for all detention basins due to the scaling procedure used to generate the FTABLES.

## Table 4.3 Stage-Volume-Discharge (FTABLE) Relations for Three Scenarios for Detention Basin No. 3

### FLOOD CONTROL (FC) SCENARIO

| DEPTH (FT) | AREA (ACRES) | VOLUME (AC-FT) | DISCH (CFS) | Detention Time Hours | *** Comment *** |
|---|---|---|---|---|---|
| 0.00 | 7.1 | 0.00 | 0.00 | | Invert Elevation |
| 1.00 | 7.3 | 7.11 | 6.66 | 12.9 | |
| 1.06 | 7.3 | 8.12 | 7.62 | 12.9 | |
| 1.42 | 7.4 | 10.46 | 12.69 | 10.0 | |
| 2.00 | 7.4 | 14.22 | 15.73 | 11.0 | |
| 2.36 | 7.5 | 16.75 | 17.77 | 11.4 | |
| 3.00 | 7.6 | 21.24 | 19.44 | 13.2 | |
| 4.00 | 7.8 | 28.35 | 22.09 | 15.6 | |
| 4.76 | 7.9 | 33.82 | 24.12 | 17.0 | |
| 5.00 | 8.0 | 35.54 | 26.79 | 16.1 | Spillway crest |
| 5.10 | 8.0 | 36.34 | 40.14 | 11.0 | |
| 5.20 | 8.1 | 37.13 | 64.54 | 7.0 | |
| 5.50 | 8.1 | 39.52 | 176.01 | 2.7 | |
| 5.70 | 8.2 | 41.11 | 273.98 | 1.8 | |
| 6.00 | 8.3 | 43.50 | 448.86 | 1.2 | |
| 10.00 | 10.0 | 70.00 | 800.00 | 1.2 | |

### FC with WATER QUALITY POOL

| DEPTH (FT) | AREA (ACRES) | VOLUME (AC-FT) | DISCH (CFS) | Detention Time hours | Comment *** *** |
|---|---|---|---|---|---|
| 0.00 | 7.1 | 0.00 | 0.00 | | Bottom of Pool/Basin |
| 2.00 | 7.1 | 14.22 | 0.00 | | Invert Elevation/Top of Perm Pool |
| 3.00 | 7.3 | 21.33 | 6.66 | 38.8 | |
| 3.06 | 7.3 | 22.34 | 7.62 | 35.6 | |
| 3.42 | 7.4 | 24.68 | 12.69 | 23.6 | |
| 4.00 | 7.4 | 28.43 | 15.73 | 21.9 | |
| 4.36 | 7.5 | 30.96 | 17.77 | 21.1 | |
| 5.00 | 7.6 | 35.46 | 19.44 | 22.1 | |
| 6.00 | 7.8 | 42.57 | 22.09 | 23.4 | |
| 6.76 | 7.9 | 48.03 | 24.12 | 24.1 | |
| 7.00 | 8.0 | 49.76 | 26.79 | 22.5 | Spillway Crest |
| 7.10 | 8.0 | 50.55 | 40.14 | 15.3 | |
| 7.20 | 8.1 | 51.35 | 64.54 | 9.6 | |
| 7.50 | 8.1 | 53.74 | 176.01 | 3.7 | |
| 7.70 | 8.2 | 55.33 | 273.98 | 2.4 | |
| 8.00 | 8.3 | 57.71 | 448.86 | 1.6 | |
| 10.00 | 10.0 | 70.00 | 800.00 | 1.6 | |

### FC with WATER QUALITY POOL and EXTENTED DETENTION

| DEPTH (FT) | AREA (ACRES) | VOLUME (AC-FT) | DISCH (CFS) | Detention Time hours | Comment *** *** |
|---|---|---|---|---|---|
| 0.00 | 7.1 | 0.00 | 0.00 | | Bottom of Pool/Basin |
| 2.00 | 7.1 | 14.22 | 0.00 | | Invert Elevation/Top of Perm Pool |
| 3.00 | 7.3 | 21.33 | 3.33 | 77.6 | |
| 3.06 | 7.3 | 22.34 | 3.81 | 71.1 | |
| 3.42 | 7.4 | 24.68 | 6.35 | 47.1 | |
| 4.00 | 7.4 | 28.43 | 7.86 | 43.8 | |
| 4.36 | 7.5 | 30.96 | 8.89 | 42.2 | |
| 5.00 | 7.6 | 35.46 | 9.72 | 44.2 | |
| 6.00 | 7.8 | 42.57 | 11.04 | 46.7 | |
| 6.76 | 7.9 | 48.03 | 12.06 | 48.3 | |
| 7.00 | 8.0 | 49.76 | 13.40 | 45.0 | Spillway Crest |
| 7.10 | 8.0 | 50.55 | 40.14 | 15.3 | |
| 7.20 | 8.1 | 51.35 | 64.54 | 9.6 | |
| 7.50 | 8.1 | 53.74 | 176.01 | 3.7 | |
| 7.70 | 8.2 | 55.33 | 273.98 | 2.4 | |
| 8.00 | 8.3 | 57.71 | 448.86 | 1.6 | |
| 10.00 | 10.0 | 70.00 | 800.00 | 1.6 | |

The impact of the water quality pool for the WQP scenario was to add **two feet of permanent storage** before the basin will discharge. Thus, both the depth and volume are increased, compared to the FC scenario, and the volume increase leads to an increase in the detention time. With the two foot permanent pool, the mean detention time at a five foot depth is 22.1 hours, an increase by a factor of 1.7 compared to the FC scenario. The range of detention times for the WQP scenario is about 21 to 39 hours. In order to maintain a permanent pool in our semi-arid climate, a source of water would be required to offset evaporative losses; within the model we represented this by eliminating evaporation from the detention basins and starting the simulations with a full permanent pool. This allowed the pool to remain full throughout the summer, for recreation and other purposes, and between storm events, without the need to define an inflow rate to the basins to offset evaporation.

The WQP/ED scenario simply adds extended detention to the WQP scenario by reducing the discharge values by a factor of 2.0 between the invert and spillway depths. This increases the detention time by a factor of 2.0 compared to the WQP scenario, and by a factor of 3.3 compared to the FC scenario. The mean detention time for WQP/ED is 44.2 hours, with a range of about 42 to 78 hours.

Prior to executing the 50-year simulations, preliminary runs were made for the 5-year water quality calibration period to help estimate sediment parameters and evaluate the general behavior and performance of the DBs. These runs indicated that the difference in shear stresses calculated for the DBs as opposed to the stream channel required some adjustments in the sediment parameters. In general, the sand coefficient and exponent values and the shear stress values for scour and deposition were increased so that sediment would scour from the DBs only at very high discharges and velocities. In effect, most all the sand deposits in the DBS, along with significant portions of the silt and clay. Since the model calculates shear stress as a function of depth, and since the depth in the DBs (especially with the permanent pool) is usually greater than in the channels, higher shear values were calculated by the model; this required the increase in the critical shear values for silt and clay to decrease the amount of scouring.

As noted in Section 3.5, the sediment bed depths and copper storages for the channels were reset to initial values on 1 July of each year to allow for bank scour and provide stability in the long-term simulations. For the DBs, we reset these depths and storages to zero each year to represent annual maintenance activities; other frequencies could have been assumed, such as every three or five years, but the annual cycle was easily represented and its impacts appeared to be minor.

In addition, for the WQP/ED and WQP/EDI scenarios, silt and clay settling velocities were increased to represent enhanced settling, under the assumption that structural and design measures (e.g. baffles, flow restrictions/diversions, vegetation, etc.) would be included to increase the settling of fine particles as a component of the overall design.

### 4.2.3 Summary of Detention Basin Assumptions and Scenarios

The baseline and scenario alternatives simulated on Calabazas Creek can be summarized as follows:

| | |
|---|---|
| 1. Baseline Condition Scenario: | Calibrated conditions for the 1982-92 period for hydrology and sediment, and for the 1987-92 period for water quality. |
| 2. Flood Control Scenario (FC): | Detention Basins (DBs) in each model segment with a **Mean Detention Time of 13.2 hours.** |
| 3. Flood Detention with Water Quality Pool Scenario (WQP): | Same as FC scenario but with a 2 foot deep permanent pool, and a **Mean Detention Time of 22.1 hours.** |
| 4. Flood Detention with Water Quality Pool and Extended Detention (**WQP/ED**): | Same as **WQP** scenario but with reduced outflow to increase detention time and increased settling, and a **Mean Detention Time of 44.2 hours.** |
| 5. Flood Detention with Water Quality Pool and Extended Detention, and located to drain mainly impervious areas (**WQP/EDI**): | Same as **WQP/ED** scenario but with detention basin drainage areas restricted to impervious areas available in each model segment. |

The key assumptions in modeling the DBs are as follows:

1. Within each model segment, 20% of the area drains directly to the DB
2. The DB drainage area is limited to residential and commercial land in each model segment, and for **WQP/EDI** the area is limited to available impervious areas in each segment.
3. The DBS are off-channel basins receiving local inflow prior to discharging directly to the stream.

4. DB size, capacity, and discharge characteristics are derived from a typical local basin for an 800 acre drainage area, and then scaled for the specific drainage areas within each model segment.

5. For the **WQP** and subsequent scenarios, no evaporation is allowed from the DBs in order to maintain the permanent pool in a semi-arid climate, assuming that inflow would be provided to offset evaporation losses.

6. Bed sediment and copper storages are reset to zero each year, such as would occur with annual maintenance activities, for stability in the long-term simulations.

7. For the **WQP/ED** scenario with extended detention, silt and clay settling rates were increased assuming structural and design measures would lead to increased removal of fine materials.

## 4.3 ANALYSIS OF SCENARIO RESULTS

The scenario results are analyzed first in terms of the impacts of the detention basins on flow and pollutant loads for each of the six detention basins simulated within the Calabazas Watershed, and then on a watershed-wide basis in terms of impacts on flows, loads, and concentrations at the watershed outlet at District gage No. 26A near Wilcox High School.

### 4.3.1 Detention Basin Results

Figure 4.1 shows the daily flow frequencies for both the inflows and outflows for DB3 for all scenarios; all the other DBs show similar curves so a complete set of these figures for each DB is included in Appendix C. Since these are daily flow-duration curves, they are generated from the 50-years of daily inflow and outflow values for the DB. Thus, the 10% exceedance level represents 1,826 daily values that were exceeded during the 50-year period (i.e. 10% of 18263 daily values in 50 years), the 1% represents 183 daily values, and the 0.2% represents about 36 values. More than 70% to 80% of the time the values are zero since these represent non-storm periods. The higher flow values at about 0.2% exceedance represent relatively frequent, moderate events since they occur many times during the 50-year period. **Readers should not confuse these exceedance values with annual flood analysis procedures where a 1% exceedance corresponds to a 100-year recurrence interval event.** See Section 4.3.2 for discussion of the annual flood peak analysis at the watershed outlet.

In Figure 4.1, there are only two inflow curves as the inflows are the same for all scenarios except the WQP/EDI which has higher inflows because it drains primarily impervious areas. There are three outflow curves as the curves for FC and WQP are identical; maintaining a permanent water quality pool has no significant impact on flow rates although it does impact water quality (as discussed below). Comparing the corresponding inflow and outflow curves shows the impact of the DB on reducing the higher flow rates and increasing the low flow rates for a wide range of storm events.

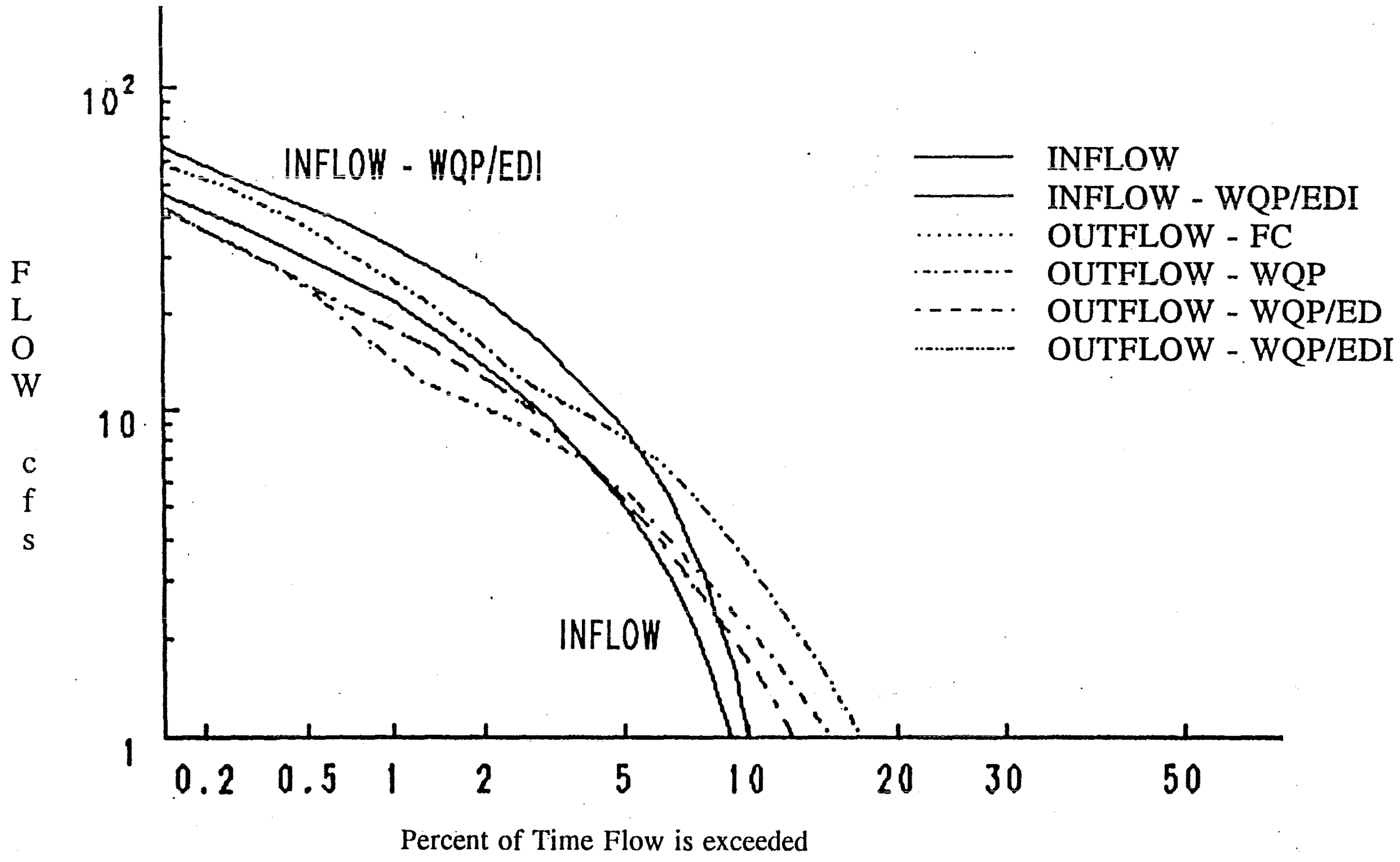

Figure 4.1 Daily Flow Frequencies for Inflow and Outflow to Detention Basin No. 3 for All Scenarios

Tables 4.4 and 4.5 show the detention basin inflow and outflow pollutant loads and removal percentages, respectively, for each detention basin. In addition, the mean values for all the six basins are calculated and shown in the tables as general summary information. The removal percentages in Table 4.5 are calculated from the 50 annual removal values for each DB from the 50-year simulation runs; they are **not** calculated from the mean loads shown in Table 4.4. Although Table 4.4 is a confusing array of numbers, focussing on the mean values across all DBs (i.e. values in **bold**) helps to note the following trends:

a. The inflow loads are the same for the first three scenarios because there is no change in the drainage area land uses tributary to the DBS. For the last scenario, WQP/EDI, the inflow loads increase significantly, i.e. 19% for sediment, 49% for copper, 29% for BOD, because the drainage areas are changed to primarily the impervious portions of each model segment.

b. The outflow loads decrease for both the WQP and the WQP/ED scenarios, compared to the FC scenario, indicating the impacts of the increased detention time and enhanced settling.

c. The outflow loads increase for the final scenario, WQP/EDI, draining impervious areas, primarily due to the increase in the inflow load noted above.

The removal percentages, or efficiencies, in Table 4.5 indicate the following:

a. The FC scenario shows significant pollutant removal for all pollutants, with mean removal efficiencies of 35% for sediment, 29% for copper, and 48% for BOD; the corresponding mean ranges are 16% to 63%, 12% to 53%, and 32% to 65%, respectively, across all the detention basins. Thus, DBs designed primarily for flood control provide complementary water quality benefits.

b. Sediment and copper removals are consistent with values from Palhegyi and Driscoll (1990) for Santa Clara County detention basins and pump stations; their range of values were 23% to 71% for sediment and 14% to 43% for copper.

c. Each of the first three scenarios shows increasing removal efficiencies with increased detention, from FC to WQP to WQP/ED.

d. The final scenario, WQP/EDI with Impervious area emphasis, is slightly less efficient than the WQP/ED but more efficient than the WQP scenario. This is likely an outcome of the higher inflow loads noted above. This may also be due to impervious areas being more stable in terms of values for both runoff and loads, since it is less impacted by antecedent conditions. Also, although loads from impervious areas are high, they do not usually show the extreme variations as do loads from pervious areas.

e. BOD generally shows the highest removal because it is subject to both settling and decay. Sediment is the next highest since settling is the dominant mechanism for detention basins, offset by a small amount of scour. Copper shows the lowest

## Table 4.4 Annual Inflow and Outflow Loads of Sediment, Copper and BOD for each Detention Basin for Different Scenarios

| | | | FLOOD CONTROL SCENARIO | | | WQ POOL SCENARIO | | | WQ POOL EXTENTED DETENTION | | | WQP+IMPERVIOUS TO DBS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max |
| **Sediment** (t) | DB1 | Inflow | 282 | 42 | 657 | 282 | 42 | 657 | 282 | 42 | 657 | 269 | 68 | 576 |
| | | Outflow | 225 | 21 | 559 | 208 | 18 | 531 | 165 | 6 | 449 | 179 | 22 | 446 |
| | DB2 | Inflow | 97 | 9 | 259 | 97 | 9 | 259 | 97 | 9 | 259 | 96 | 20 | 249 |
| | | Outflow | 71 | 3 | 208 | 65 | 3 | 194 | 46 | 1 | 150 | 56 | 4 | 164 |
| | DB3 | Inflow | 207 | 30 | 563 | 207 | 30 | 563 | 207 | 30 | 563 | 257 | 59 | 665 |
| | | Outflow | 155 | 11 | 459 | 141 | 10 | 426 | 103 | 3 | 337 | 153 | 14 | 449 |
| | DB4 | Inflow | 80 | 16 | 216 | 80 | 16 | 216 | 80 | 16 | 216 | 117 | 25 | 309 |
| | | Outflow | 57 | 6 | 169 | 52 | 5 | 155 | 35 | 2 | 116 | 59 | 4 | 179 |
| | DB5 | Inflow | 79 | 14 | 223 | 79 | 14 | 223 | 79 | 14 | 223 | 146 | 30 | 390 |
| | | Outflow | 50 | 4 | 166 | 46 | 4 | 152 | 28 | 1 | 108 | 69 | 4 | 220 |
| | DB6 | Inflow | 11 | 2 | 33 | 11 | 2 | 33 | 11 | 2 | 33 | 14 | 3 | 39 |
| | | Outflow | 7 | 1 | 23 | 6 | 0.5 | 21 | 3 | 0.1 | 15 | 6 | 0.3 | 20 |
| | **Mean** | **Inflow** | **126** | **19** | **325** | **126** | **19** | **325** | **126** | **19** | **325** | **150** | **34** | **371** |
| | | **Outflow** | **94** | **8** | **264** | **86** | **7** | **247** | **63** | **2** | **196** | **87** | **8** | **246** |
| **Copper** (lbs) | DB1 | Inflow | 135 | 23 | 308 | 135 | 23 | 308 | 135 | 23 | 308 | 150 | 39 | 317 |
| | | Outflow | 114 | 14 | 280 | 109 | 14 | 271 | 91 | 8 | 241 | 113 | 18 | 267 |
| | DB2 | Inflow | 47 | 5 | 124 | 47 | 5 | 124 | 47 | 5 | 124 | 56 | 12 | 144 |
| | | Outflow | 37 | 2 | 108 | 35 | 3 | 104 | 28 | 2 | 88 | 39 | 5 | 111 |
| | DB3 | Inflow | 137 | 23 | 368 | 137 | 23 | 368 | 137 | 23 | 368 | 216 | 50 | 560 |
| | | Outflow | 110 | 11 | 322 | 106 | 12 | 310 | 85 | 7 | 265 | 154 | 22 | 433 |
| | DB4 | Inflow | 71 | 14 | 189 | 71 | 14 | 189 | 71 | 14 | 189 | 113 | 25 | 297 |
| | | Outflow | 54 | 7 | 157 | 51 | 7 | 149 | 38 | 4 | 120 | 66 | 7 | 194 |
| | DB5 | Inflow | 62 | 12 | 172 | 62 | 12 | 172 | 62 | 12 | 172 | 140 | 29 | 373 |
| | | Outflow | 43 | 5 | 136 | 41 | 5 | 129 | 28 | 3 | 99 | 78 | 8 | 234 |
| | DB6 | Inflow | 9 | 2 | 25 | 9 | 2 | 25 | 9 | 2 | 25 | 12 | 2 | 32 |
| | | Outflow | 6 | 1 | 20 | 6 | 1 | 19 | 4 | 0.4 | 14 | 7 | 1 | 20 |
| | **Mean** | **Inflow** | **77** | **13** | **198** | **77** | **13** | **198** | **77** | **13** | **198** | **115** | **26** | **287** |
| | | **Outflow** | **61** | **7** | **171** | **58** | **7** | **164** | **46** | **4** | **138** | **76** | **10** | **210** |
| **BOD** (lbs) | DB1 | Inflow | 7788 | 3060 | 15920 | 7788 | 3060 | 15920 | 7788 | 3060 | 15920 | 7418 | 4955 | 11220 |
| | | Outflow | 5105 | 1235 | 11930 | 4524 | 835 | 11130 | 4243 | 665 | 10720 | 3710 | 1731 | 6879 |
| | DB2 | Inflow | 3941 | 1603 | 8075 | 3941 | 1603 | 8075 | 3941 | 1603 | 8075 | 4686 | 2994 | 6597 |
| | | Outflow | 2245 | 475 | 5297 | 1890 | 343 | 4782 | 1722 | 265 | 4509 | 1977 | 1013 | 3305 |
| | DB3 | Inflow | 10716 | 5879 | 19570 | 10716 | 5879 | 19570 | 10716 | 5879 | 19570 | 14570 | 9146 | 19250 |
| | | Outflow | 5777 | 2020 | 12200 | 4832 | 1493 | 10750 | 4281 | 1163 | 9891 | 5974 | 3223 | 9029 |
| | DB4 | Inflow | 4094 | 2246 | 6516 | 4094 | 2246 | 6516 | 4094 | 2246 | 6516 | 5442 | 3318 | 7548 |
| | | Outflow | 2098 | 1000 | 3640 | 1722 | 762 | 3212 | 1463 | 595 | 2832 | 2049 | 1043 | 3212 |
| | DB5 | Inflow | 3974 | 2106 | 6915 | 3974 | 2106 | 6915 | 3974 | 2106 | 6915 | 7030 | 4265 | 10030 |
| | | Outflow | 1874 | 863 | 3747 | 1474 | 558 | 3160 | 1234 | 432 | 2795 | 2532 | 1221 | 4031 |
| | DB6 | Inflow | 836 | 449 | 1504 | 836 | 449 | 1504 | 836 | 449 | 1504 | 1128 | 688 | 1637 |
| | | Outflow | 396 | 188 | 818 | 312 | 118 | 682 | 260 | 92 | 601 | 397 | 188 | 637 |
| | **Mean** | **Inflow** | **5225** | **2557** | **9750** | **5225** | **2557** | **9750** | **5225** | **2557** | **9750** | **6712** | **4228** | **9380** |
| | | **Outflow** | **2916** | **964** | **6272** | **2459** | **685** | **5619** | **2201** | **535** | **5225** | **2773** | **1403** | **4516** |

## Table 4.5 Percent Removal of Sediment, Copper and BOD in Detention Basins for Different Scenarios

| | | **Flood Control Scenario** | | | **WQ Pool Scenario** | | | **WQ Pool Extented Detention** | | | **WQP+Impervious to DBs** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max |
| **Sediment** | DB1 | 24 | 12 | 50 | 30 | 15 | 56 | 47 | 22 | 85 | 38 | 17 | 68 |
| | DB2 | 34 | 16 | 68 | 41 | 20 | 72 | 62 | 29 | 94 | 47 | 22 | 78 |
| | DB3 | 32 | 14 | 63 | 39 | 19 | 67 | 60 | 29 | 91 | 45 | 21 | 76 |
| | DB4 | 34 | 15 | 59 | 41 | 20 | 65 | 63 | 32 | 90 | 56 | 27 | 84 |
| | DB5 | 43 | 18 | 69 | 48 | 24 | 72 | 73 | 36 | 94 | 59 | 29 | 87 |
| | DB6 | 45 | 19 | 70 | 51 | 24 | 73 | 77 | 37 | 95 | 66 | 35 | 91 |
| | **Mean** | **35** | **16** | **63** | **42** | **20** | **68** | **64** | **31** | **92** | **52** | **25** | **81** |
| **Copper** | DB1 | 18 | 7 | 41 | 22 | 9 | 43 | 37 | 15 | 66 | 28 | 12 | 53 |
| | DB2 | 27 | 10 | 57 | 29 | 13 | 48 | 48 | 22 | 74 | 33 | 15 | 56 |
| | DB3 | 25 | 10 | 52 | 27 | 12 | 46 | 45 | 20 | 68 | 32 | 15 | 55 |
| | DB4 | 28 | 12 | 51 | 32 | 16 | 50 | 51 | 26 | 73 | 46 | 22 | 70 |
| | DB5 | 37 | 15 | 60 | 39 | 19 | 56 | 60 | 32 | 77 | 50 | 25 | 73 |
| | DB6 | 37 | 16 | 59 | 38 | 20 | 51 | 60 | 32 | 72 | 50 | 27 | 69 |
| | **Mean** | **29** | **12** | **53** | **31** | **15** | **49** | **50** | **24** | **72** | **40** | **19** | **63** |
| **BOD** | DB1 | 37 | 22 | 60 | 45 | 26 | 73 | 49 | 28 | 78 | 51 | 36 | 69 |
| | DB2 | 46 | 25 | 70 | 56 | 32 | 79 | 60 | 35 | 83 | 58 | 44 | 72 |
| | DB3 | 48 | 31 | 67 | 57 | 38 | 76 | 63 | 42 | 81 | 59 | 46 | 71 |
| | DB4 | 49 | 38 | 59 | 59 | 44 | 74 | 65 | 49 | 80 | 63 | 48 | 76 |
| | DB5 | 54 | 38 | 65 | 64 | 48 | 79 | 70 | 52 | 84 | 64 | 49 | 78 |
| | DB6 | 54 | 37 | 66 | 64 | 46 | 79 | 70 | 51 | 83 | 65 | 50 | 78 |
| | **Mean** | **48** | **32** | **65** | **58** | **39** | **76** | **63** | **43** | **82** | **60** | **46** | **74** |

removals because it settles to the bed but can return to the water column through chemical desorption from the bed to the overlying water. Thus the losses through settling are somewhat offset by gains from the stream bed.

f. There are differences in removal efficiencies across the DBs due to variation in both inflow rates and loads. The DBs in the upper watershed (e.g. DB1, DB3) tend to demonstrate less removal efficiency than those in the lower watershed (e.g. DB5, DB6) due to higher slopes and rainfall, and associated runoff and loads.

### 4.3.2 Calabazas Creek Watershed Results

To evaluate the impact of the alternative scenarios at a watershed scale a variety of analyses were performed on flow volumes, flow rates, pollutant loads, and concentrations. Table 4.6 summarizes the 50-year simulation results for all scenarios for the Calabazas Creek Watershed at Wilcox High School in terms of mean annual flow volume, daily and hourly flow and frequency, and annual pollutant loads. Note that the results for the hourly flow simulation are presented only for relative comparisons among the various alternatives; hydrologic calibration was limited to average daily flows without sufficient resources for detailed comparisons of storm hydrographs.

The results in Table 4.6 indicate the following:

a. None of the scenarios have a significant impact on mean annual flow volumes, except for a slight increase for the WQ scenarios. Since evaporation was eliminated from the DBs in the WQ scenarios (as noted above) to maintain a permanent pool, the annual volumes increase slightly for these scenarios.

b. For Daily Flows, two simulated peaks are shown to demonstrate the impact of the scenarios on specific storm peak values; these values are the two largest simulated peaks during the 50-year period. For 1963, little change is shown in the peak value, and the peak actually increases for all scenarios, while the 1968 peak shows a small but consistent reduction.

c. Under the Log Pearson Type III (LP3) analysis for Daily Flows, little or no difference is evident between FC and WQP flow rates, possibly due to the detention times of 12 to 22 hours but less than one day. Flow rates actually increase (for storms of 5-years or greater) under the WQP/ED and WQP/EDI scenarios with the extended detention, demonstrating the classic conflict between conserving available storage for flood control while maintaining water levels for WQ improvement (and other uses).

d. For the Daily Flows, more frequent events show some decrease in flow rates, i.e 10-year return period (recurrence interval) or less, while the less frequent (more extreme) events show little change, and actually some small increase in peak flow rates.

# Table 4.6 Scenario Simulation Results (50-years) for Alternative Scenarios for the Calabazas Creek Watershed at Wilcox High School

| **Station** | **Constituent** | **Baseline Condition** | **Flood Control** | **WQ Pool** | **WQ Pool Ext. Detn** | **WQP Ext Impr** |
|---|---|---|---|---|---|---|
| **WILCOX HIGH SCHOOL** | | | | | | |
| | **MEAN ANNUAL FLOW** (in) | 11.56 | 11.57 | 11.60 | 11.60 | 11.60 |
| | **DAILY FLOW (cfs)** | | | | | |
| | SIMULATED PEAK (cfs) | | | | | |
| | 1963 | 1332 | 1350 | 1350 | 1344 | 1342 |
| | 1968 | 2140 | 2116 | 2116 | 2119 | 2136 |
| | LOG PEARSON TYPE III ANALYSIS | | | | | |
| | RECURRENCE INTERVAL | | | | | |
| | 1 | 108 | 99 | 99 | 94 | 85 |
| | 2 | 479 | 451 | 451 | 446 | 450 |
| | 5 | 759 | 730 | 731 | 773 | 741 |
| | 10 | 951 | 928 | 928 | 934 | 942 |
| | 25 | 1196 | 1185 | 1186 | 1196 | 1198 |
| | 50 | 1378 | 1382 | 1382 | 1393 | 1389 |
| | 100 | 1559 | 1580 | 1580 | 1591 | 1577 |
| | **HOURLY FLOW (cfs)** | | | | | |
| | SIMULATED PEAK (cfs) | | | | | |
| | 1968 | 8526 | 7717 | 7795 | 7956 | 8343 |
| | 1980 | 8042 | 7753 | 7778 | 7813 | 7833 |
| | LOG PEARSON TYPE III ANALYSIS | | | | | |
| | Recurrence Interval | | | | | |
| | 1 | 575 | 400 | 400 | 385 | 301 |
| | 2 | 3091 | 2686 | 2690 | 2734 | 2819 |
| | 5 | 5119 | 4705 | 4717 | 4820 | 5058 |
| | 10 | 6526 | 6148 | 6168 | 6302 | 6577 |
| | 25 | 8327 | 8027 | 8059 | 8219 | 8440 |
| | 50 | 9667 | 9441 | 9483 | 9651 | 9758 |
| | 100 | 10997 | 10853 | 10908 | 11073 | 11004 |
| | **MEAN ANNUAL LOADS** | | | | | |
| | Sediment (t) | 8287 | 7692 | 7645 | 7522 | 7452 |
| | Copper (lbs) | 2224 | 2130 | 2113 | 2040 | 1998 |
| | BOD (lbs) | 132516 | 118139 | 115795 | 114278 | 109047 |
| | **% LOAD REDUCTION FROM BASELINE** | | | | | |
| | Sediment | - | 7.2 | 7.7 | 9.2 | 10.1 |
| | Copper | - | 4.2 | 5.0 | 8.3 | 10.2 |
| | BOD | - | 10.8 | 12.6 | 13.8 | 17.7 |

e. Similar conclusions are shown by the simulated hourly flow values, but as expected the hourly values show the reduction in peaks due to detention. Reductions are greatest for the FC scenario, and are progressively reduced (i.e. peak flow rates increase) as the detention time increases -- storages are not depleted fast enough following storms to be available for flood control for subsequent storms.

   It should be noted again that the absolute hourly values in Table 4.6 should be viewed with caution, with greater emphasis on the relative changes among the scenarios. The lack of calibration to storm peak flows, and the nature of the Log Pearson III analysis leads to an over-estimation of the peak hourly values. Use of a Pearson III analysis, as opposed to the Log Pearson, produced peaks that are 20% to 30% lower than the ones shown in Table 4.6.

f. The overall watershed impacts are generally small partly due to only 20% of the watershed being controlled by the DBs, and the controlled area is spread uniformly across the watershed. If the DBs reduce the peaks on their drainage areas by 20% to 30%, the reduction at the watershed outlet would be in the range of 4% to 6%, under these assumptions. However, if the 20% was concentrated in the upper watershed that receives the greatest rainfall amounts, the peak reductions would have likely been much greater.

g. The mean annual loads and percent reductions from the baseline scenario, shown at the bottom of Table 4.6, indicate results consistent with the detention basin simulation discussed in Section 4.3.1. The loads are progressively reduced from the FC to each of the WQ scenarios. The BOD loads show the largest reductions, sediment shows the next largest, with copper reductions begin the smallest.

h. The % reductions, in many cases, can be approximated by taking 20% of the mean DB reductions shown in Table 4.5, indicating the approximate linear nature of the impact of the watershed area drained by the DBs. Thus, for example, increasing the DB drainage to 40% of the watershed would likely lead to % reductions twice those shown in Table 4.6.

Figures 4.2 through 4.6 show the flow and concentration frequencies for all scenarios at the Wilcox High School site (District Gage No. 26A). These curves are the results of analysis of the daily flow and concentration timeseries generated for the 50-year simulation period (i.e. 18,263 values). In these curves the 'Percent of Time' scale indicates the percent of the 18,263 values when the corresponding flow or concentration is exceeded. Since the flow rates are less than 1.0 cfs (and approach zero) much of the time, and concentrations also approach zero during these conditions (e.g. during summer and fall), the curves show significant values only 10% to 50% of the time; the rest of the time the values are negligible or zero.

Comparing the frequency results of the alternative scenarios provides a means of evaluating how the scenario affects watershed behavior for the entire range of possible events, both common and extreme. Thus, a 10% exceedance value indicates that the daily flow or concentration exceeded the corresponding value (i.e. on the opposite scale) for 1,826 days in the 50-year period, a 1% value corresponds to 183 days, 0.1% to 18 days, and 0.01% to 2 days. Thus, values for exceedances of 0.1% or less would correspond to extreme events, whereas a 1.0% value indicates a daily flow or concentration that would be exceeded, on the average, in three to four events each year. **Readers should not confuse these exceedance values with annual flood analysis procedures where a 1% exceedance corresponds to a 100-year recurrence interval event.**

Review and comparison of the frequency results indicates the following:

a. The daily flow frequency curves in Figure 4.2 show very little impact of the DBs on the daily flows; the higher values are slightly reduced and the lower baseflow values are slightly increased. Performing the same analysis on the maximum hourly values during each year (not shown here) indicates somewhat larger differences. The small impact is likely due to the small fraction of watershed controlled by DBs, especially with much of the flow originating from the upper portions of the watershed with the highest rainfall amounts. Earlier we noted the significant impact of the DBs in reducing the inflows compared to the outflows, but the aggregate watershed impact depends on the fraction of the area and locations of the DBs.

b. The sediment results shown in Figure 4.3 show a clear reduction in sediment concentrations for all scenarios compared to the Baseline Condition. Although the curves appear to cross at low sediment concentrations, less than about 100 mg/l, the Baseline values clearly diverge from the other scenarios for higher concentrations. There is very little difference between and among the FC and all WQ scenarios, in spite of the increasing load reductions shown above in Table 4.6 for the WQ alternatives. Thus, the net effect of changes in both flow and load appear to have offsetting impacts on sediment concentrations, i.e. both flow and sediment load are reduced such that concentration changes are small.

c. In Figure 4.4, the dissolved copper concentrations show reductions of the higher values comparing the Baseline with the FC and WQ scenarios, but the opposite is true (i.e. increasing concentrations) at the lower concentrations. Below about 10 ug/l, the FC and WQ scenarios show higher copper concentrations due to the detention time in the basins and the resulting exchange with copper in the bed (as discussed above). Above the 10 -12 ug/l level, the Baseline shows the higher values, FC shows the lowest, and the WQ scenarios are in between. Since Table 4.6 shows increasing load reductions for each WQ scenario, these differences in dissolved concentrations have very little impact on the total load because most of it is transported with sediment.

d. The Total Copper concentrations in Figure 4.5 show results similar to the sediment concentrations, with the Baseline curve clearly indicating higher values in the range above about 100 ug/l. Below that level, the curves are all close together down to about 50 ug/l, and then the Baseline appears to show the smallest values at the very low concentrations. Although the WQP/EDI scenario shows the largest load reductions in Table 4.6, its concentrations appear to be higher than the other alternatives. This could be due to the higher loadings to the detention basins, noted above, and the resulting increased copper exchange with the bed.

e. The BOD concentrations in Figure 4.6 show the impact of the increased detention times under the WQ scenarios allowing additional decay and settling to occur compared to the values under the Baseline Condition. The WQP/EDI scenario shows the lowest concentrations as a result of the DBs receiving more of the BOD from the impervious areas, resulting in greater absolute reductions in the total load; Table 4.6 shows almost 18% reduction in load under this scenario.

   One anomaly is an apparent increase in BOD concentrations under the FC scenario as compared to the Baseline. Although the differences are small, except for the extreme peak during the entire period, they are consistent for all concentrations exceeded less than 10% of the time. Apparently individual flows are reduced enough to offset the load reductions from the DBs, leading to a small increase in concentration.

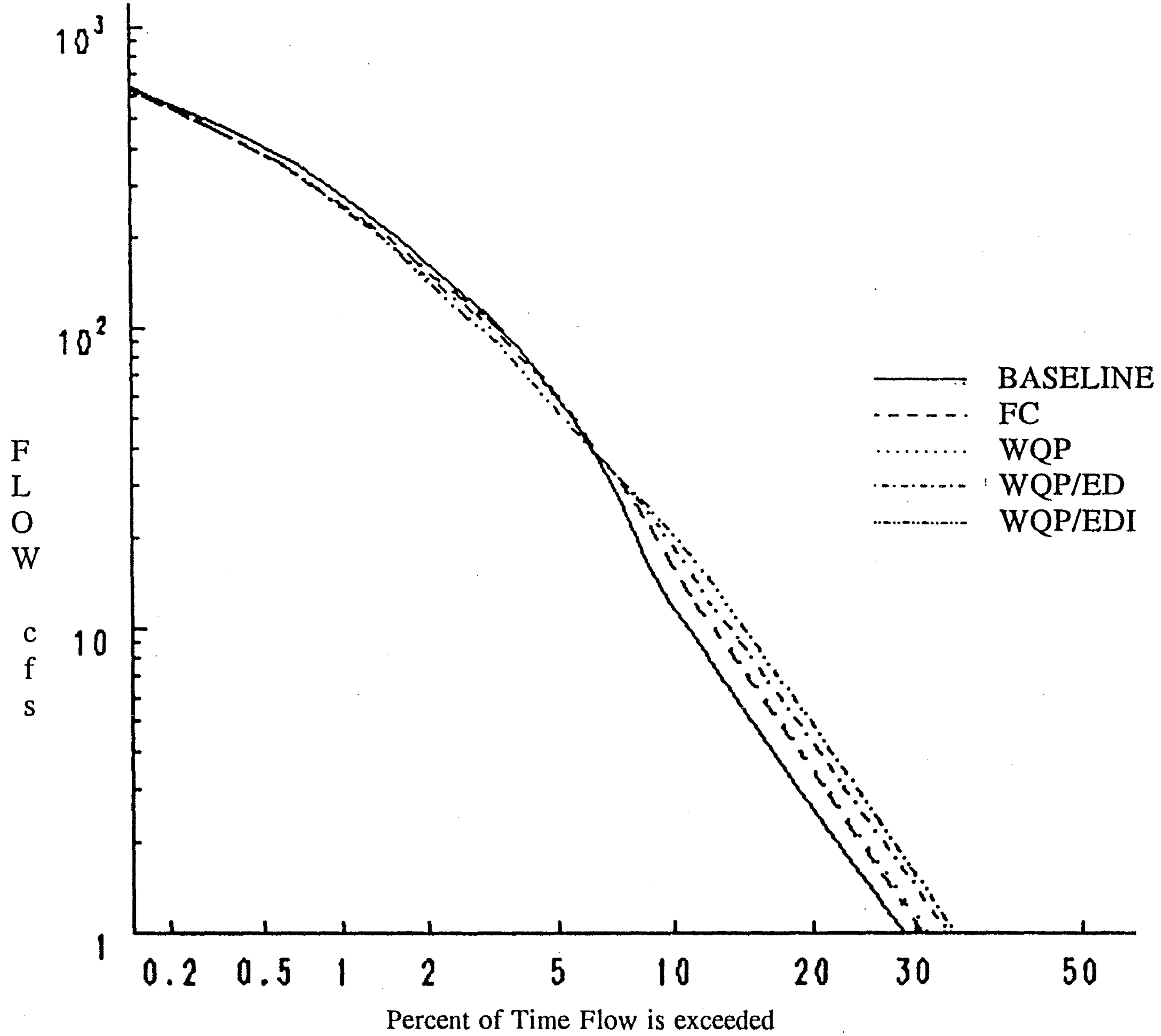

Figure 4.2 Flow Frequency for All Scenarios on the Calabazas Creek Watershed at Wilcox High School

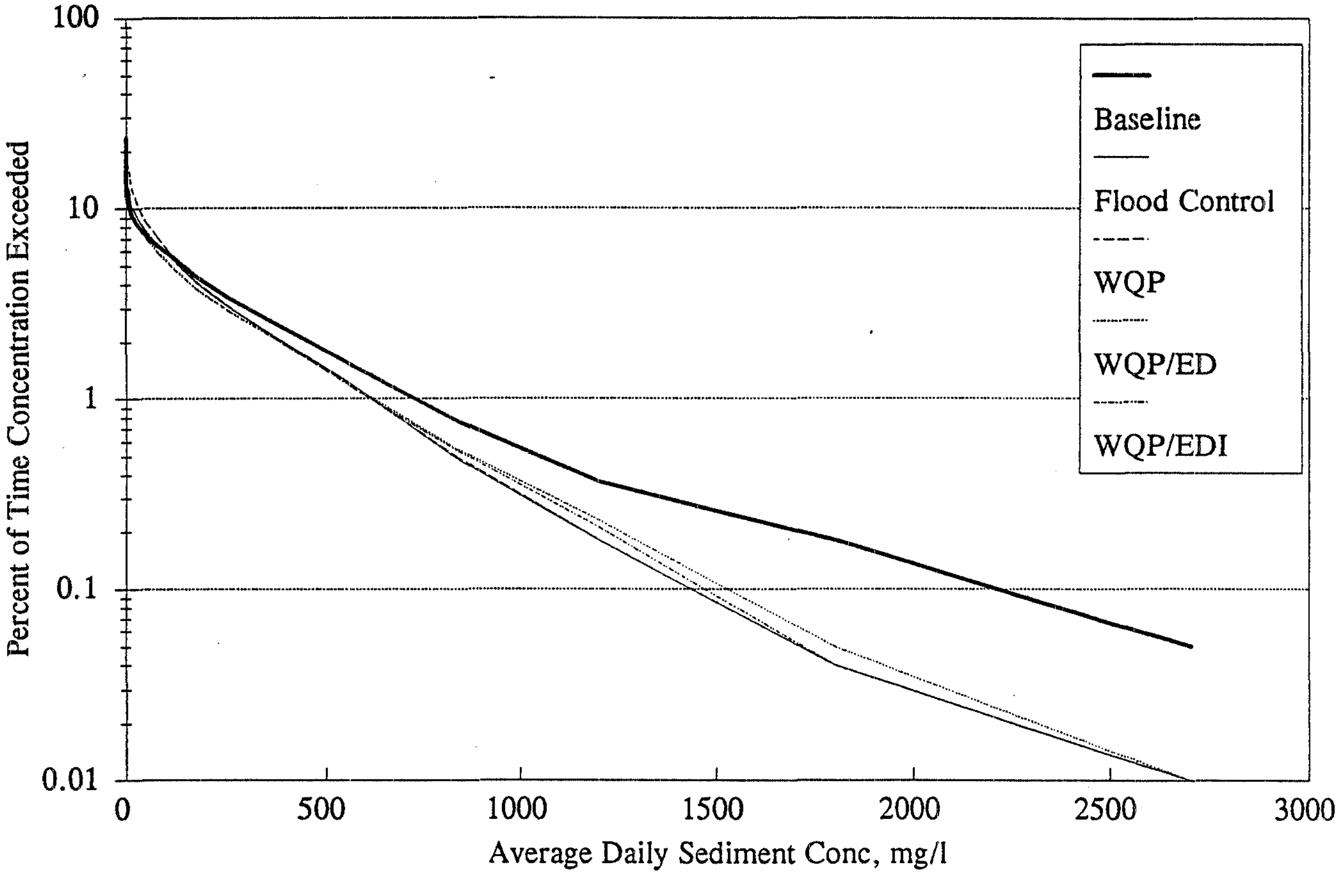

Figure 4.3 Sediment Concentration Frequency for All Scenarios on the Calabazas Creek Watershed at Wilcox High School

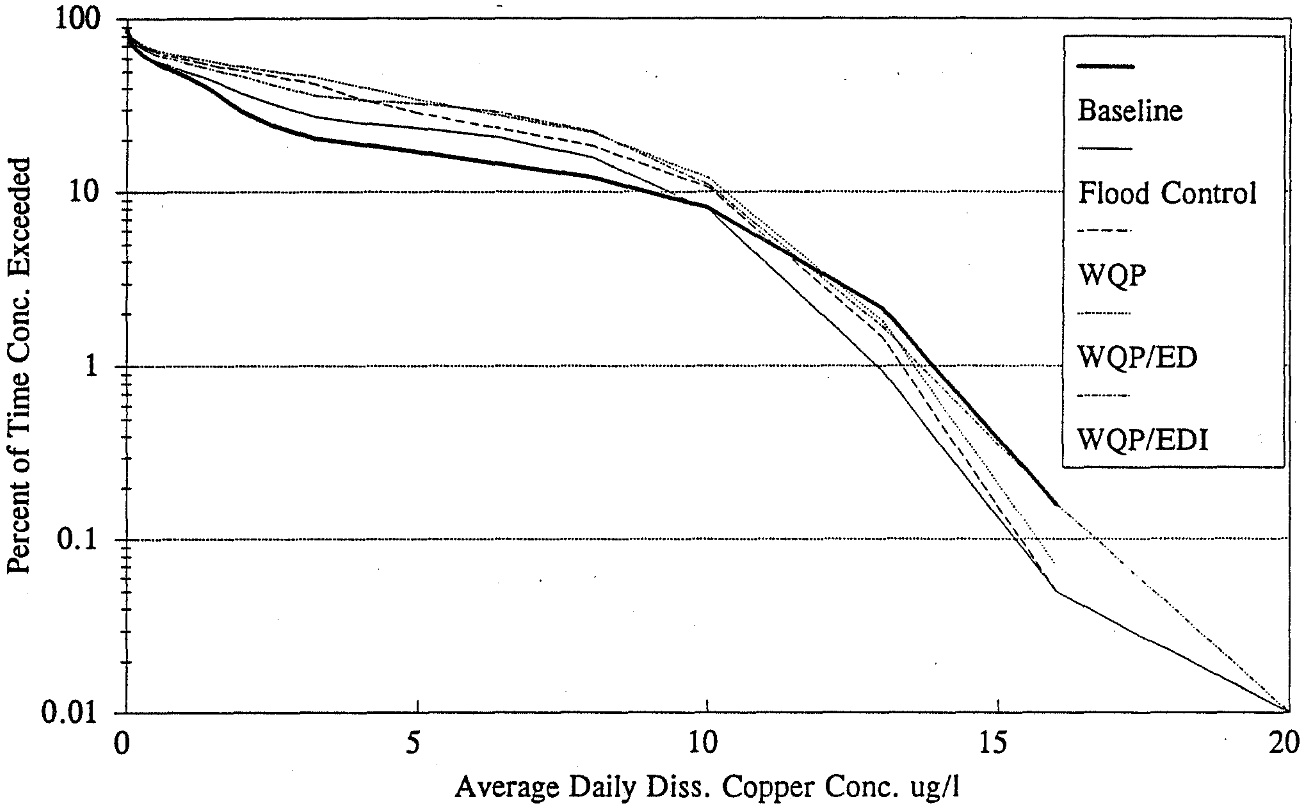

Figure 4.4 Dissolved Copper Concentration Frequency for All Scenarios on the Calabazas Creek Watershed at Wilcox High School

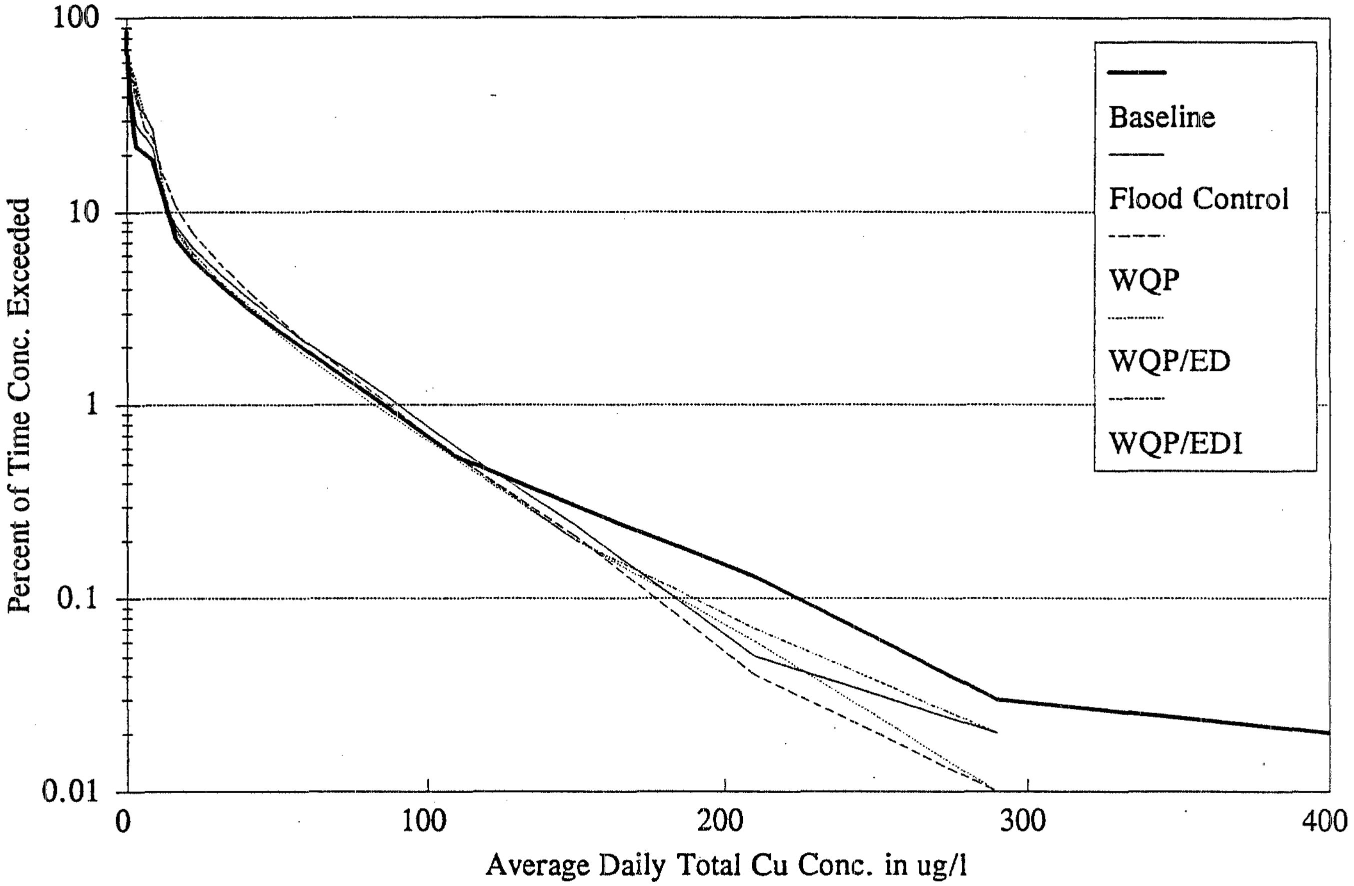

Figure 4.5 Total Copper Concentration Frequency for All Scenarios on the Calabazas Creek Watershed at Wilcox High School

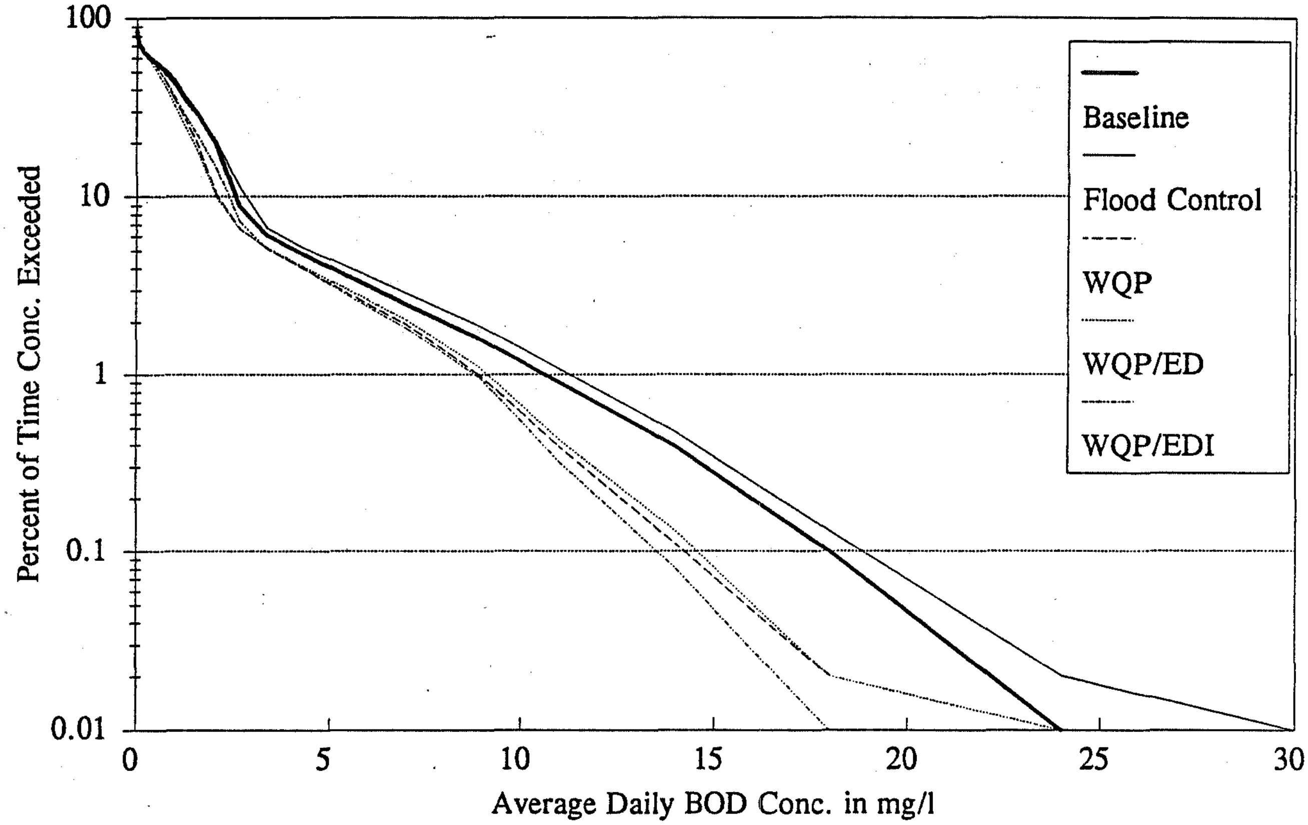

Figure 4.6 BOD Concentration Frequency for All Scenarios on the Calabazas Creek Watershed at Wilcox High School

# SECTION 5.0

# STUDY CONCLUSIONS AND RECOMMENDATIONS

## 5.1 STUDY CONCLUSIONS AND LIMITATIONS

The Calabazas Creek Watershed model based on the U.S. EPA HSPF program provides a sound and viable representation of the dynamic watershed behavior of hydrology, sediment, copper, and BOD loadings and concentrations. The model was calibrated and verified for hydrology for a 10-year period, and calibrated for the water quality constituents for a five-year period. The model was run continuously over these time periods with the primary focus on representing daily flows and storm event mean concentrations. The model results demonstrated a capability to reproduce flows and concentrations that spanned the range and mimicked the dynamic nature of the watershed as shown by the observed data.

Through the model application process described in this report, the HSPF model of the Calabazas Creek Watershed demonstrates the representation needed to evaluate likely impacts of alternative detention scenarios on both hydrology and water quality. Based on the model results for both the Baseline Condition and the Water Quality detention scenarios simulated for the Calabazas Creek Watershed, the following study conclusions are presented:

a. Detention basins designed primarily for flood control can provide complementary and significant water quality benefits through settling and decay of constituents due to the added detention time.

b. Detention times, in the range of at least 12 to 48 hours, can provide significant reductions for both flood peaks and pollutants loads. However, the degree of flood peak reduction diminishes with the longer detention times. Further studies should be conducted to evaluate impacts of both shorter (e.g. 4 to 8 hours) and longer (e.g. 3 to 7 days) detention times.

c. The degree of pollutant load reduction by detention basins depends on the characteristics of the specific pollutants of concern. In our simulations, the largest reductions were demonstrated for BOD which undergoes losses by both setting and decay; removal percentages for BOD showed a mean of 48% and a range of 32% to 65%. Other nonconservative constituents, such as nutrients, can be expected to behave in a similar manner with losses increasing with the longer detention times.

d. Our simulations of conservative pollutants, such as sediment and copper, indicated the following conclusions:

    i. Sediment and copper demonstrated mean removals of 35% and 29%, respectively, with ranges of 16% to 62%, and 12% to 53%.

    ii. For sediment, the DBs settled all the sand particles and a portion of the silt and clay; these fine particle fractions are sensitive to the settling velocity parameters in the model.

    iii. Although copper is transported primarily on sediment, it also desorbs back into the overlying water after it has settled to the bed in the DBs. This tends to reduce the net removal by the DB.

    iv. The use of sediment removal efficiencies to estimate metals removals in DBs will tend to over-estimate actual removal efficiencies for metals. It is expected that other metals will behave in a similar fashion, with the amount returned through bed desorption depending on the partition coefficient of the particular metal.

e. The degree of watershed impact depends on both the size of the watershed and the amount of drainage area tributary to, and controlled by, the DBs. In our studies, the changes in flow and load at the watershed outlet were relatively small because only 20% of the area was assumed to drain to the DBs. With larger fractions of the watershed draining to a DB, e.g. 30% to 50%, much greater changes on both flood peak and contaminant load reduction would be expected at the watershed outlet, and further downstream to the Bay. However, increasing the areas controlled will require larger DBs and more land, and thereby increasing costs, so that economic tradeoffs would need to be considered.

f. Locations of the DBs within the watershed will also affect the degree of flood peak and nonpoint load reduction. Our studies showed that locating the DBs to drain high nonpoint load sources (e.g. impervious areas) produces greater load reductions at the watershed outlet than if the DBs drained the same land use distribution as in the model segment. For flood reduction, locating the DBs in the upper watershed with the higher rainfall, steeper slopes, and greater runoff would likely have had a greater effect than uniformly locating the DBs throughout the watershed. Location decisions may require an analysis of tradeoffs between flood control and water quality, since the best location for flood control may not be the best for downstream water quality improvement. A watershed model like the one used in this study is an ideal tool for evaluating the potential impacts of DBs on flooding and water quality for alternative locations.

g. Although a limited number of scenarios were investigated in this study, the model can be used to investigate and evaluate the expected impact of alternative DB designs, e.g.

multiple ponds, alternative inflow/outflow structures, baffles/diversions, different operating procedures, vegetated banks and filtration areas, etc. Although ancillary benefits were not evaluated in this study, DBs with permanent pools can be designed and landscaped to provide for recreation and wildlife habitat, and can be integrated into, or provide the centerpiece, for local and/or regional parks.

Any model is only an approximation of reality; the models' utility depends on its' ability to provide a reasonable and sufficient representation of the key behavioral characteristics of the watershed so that it can be used as an effective tool to assess the likely impacts of alternative conditions. All models have limitations and there are limitations or assumptions in how they are applied in a given setting. Often an awareness of the model's assumptions and limitations is as important as the knowledge of its capabilities. HSPF has many limitations, but less than most watershed models. In this study, some key model and application limitations are evident. One model limitation is that copper is represented in only dissolved and sorbed phases, so that multiple dissolved species are not included. Application limitations include: (1) the model was calibrated to average daily storm peaks and EMCs, but not to storm hydrographs; and (2) the DBs were not site-specific designs, but generic refinements of a District design to represent detention impacts. Additional limitations and assumptions are noted in the description of HSPF (Section 2.2) and the DB simulations (Section 4.2.2).

## 5.2 RECOMMENDATIONS

Based on our watershed and DB modeling investigations, and our review of the literature, it is apparent that the District should consider the impacts of newly proposed and designed DBs on nonpoint loads and water quality. To this end we recommend the following procedures and conceptual criteria for all new facilities:

a. The potential impacts of proposed DB designs on nonpoint load reduction should be assessed, and credit should be given in terms of load reductions to the Bay. The amount of reduction will depend on both DB design and operating characteristics, and pollutant characteristics. Removal efficiencies for metals should not be based on sediment removal values as this will tend to over-estimate actual metal removal of a DB.

b. Alternative longer detention times, from 12 to 60 hours or more should be assessed to determine the increased load reduction and water quality benefits that may accrue. Clearly, the longer times must also be evaluated in terms of negative impacts for flood control such as lesser reductions of peak flows.

c. The flood control and water quality impacts of proposed DBs need to be evaluated at both the local scale (i.e. at the outlet of the DB), and at the watershed scale. Impacts, such as changes in flood peaks and pollutant concentrations, may be small or negligible if less than 10% to 20% of the watershed is controlled by DBs. However, these impacts will be greater if additional DBs are approved and constructed within the watershed.

d. Since DBs are essentially 'treatment' options for reducing urban nonpoint pollutant loads, they should be evaluated in conjunction with 'source control' options that reduce the generation of nonpoint loads. Although source controls were not a focus of this study, our model simulations showed that water quality is very sensitive to local nonpoint loads. Comprehensive pollution control approaches, with both treatment and source control components, need to be evaluated at both the local and the watershed scale. The District should consider watershed modeling as a tool for this type of comprehensive pollution control and management.

The Calabazas Creek Watershed model provides a capability for investigating a wide range of additional scenarios and alternatives for both DB design and watershed-scale impacts. To help further refine the study conclusions, the following recommendations should be considered by the District:

a. Additional simulations should be performed with an increased area draining to the DBs, e.g. 30% to 50% of watershed area.

b. DBs with both shorter (e.g. 4 to 8 hours) and longer (e.g. 3 to 7 days) detention times should be modeled to refine the range of detention times where flood control is, or may be, seriously reduced in exchange for improved water quality.

c. Alternative locations of DBs should be investigated to explore the types of conflicts likely to develop between flood control and nonpoint source reduction goals, and investigate possible compromises and solutions.

d. Additional DB designs should be simulated, e.g. multiple pools, off-channel storage, alternative inflow/outflow structures, etc. in order to explore a wider range of alternative DB configurations and operating procedures. These potential alternatives could help to achieve an more balanced tradeoff between acceptable levels of flood peak reduction and water quality improvement.

e. Since DBs are essentially 'treatment' options for reducing urban runoff pollutant loads, they should be evaluated in conjunction with 'source control' options that reduce the generation of nonpoint loads. A watershed model, like the Calabazas Creek Watershed model, can be used to analyze the tradeoffs between treatment and source control alternatives to help design a watershed plan that includes an effective mix of both control approaches.

Although the HSPF application to the Calabazas Creek watershed showed reasonable calibration results and a good representation of the available observed data, further improvement is possible and is recommended. Recommendations for improving the model representation include the following:

a. Further calibration of the model with specific emphasis on individual storm events and peaks should be pursued to establish the ability to match short interval storm flood peaks. Lawn watering and point source flows should be included in future simulations, and the long-term record used to generate the scenario results should be further investigated to insure a valid representation of the watershed meteorologic conditions.

b. The model calibration and simulation period should be extended through 1996 to take advantage of the more recent and more reliable water quality data collected in the last few years.

c. Selected model parameters, such as the sediment settling velocities and bed exchange rates should be further investigated to establish their sensitivity and help further refine their calibrated values.

d. Additional pollutants should be modeled, such as alternative metals and nutrients, in order to include the capability to evaluate the influence of DBs on other metals of concern (e.g. nickel, lead, zinc) and nutrients (e.g. nitrogen and phosphorus forms).

e. Refined segmentation of land uses, model segments, and channel segments would produce a more flexible and versatile model for examining channel behavior in greater detail, along with the impacts of alternative specific DB locations.

# SECTION 6.0

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# APPENDIX A.

# CALABAZAS CREEK DAILY HYDROLOGY CALIBRATION AND VERIFICATION RESULTS

## Calabazas Creek Hydrology Calibration

Simulated and Observed Daily Flow at Wilcox High School, 1982-83
Simulated and Observed Daily Flow at Wilcox High School, 1983-84
Simulated and Observed Daily Flow at Wilcox High School, 1984-85
Simulated and Observed Daily Flow at Wilcox High School, 1985-86
Simulated and Observed Daily Flow at Wilcox High School, 1986-87
Simulated and Observed Daily Flow at Wilcox High School, 1987-88
Simulated and Observed Daily Flow at Wilcox High School, 1988-89
Simulated and Observed Daily Flow at Wilcox High School, 1989-90
Simulated and Observed Daily Flow at Wilcox High School, 1990-91
Simulated and Observed Daily Flow at Wilcox High School, 1991-92

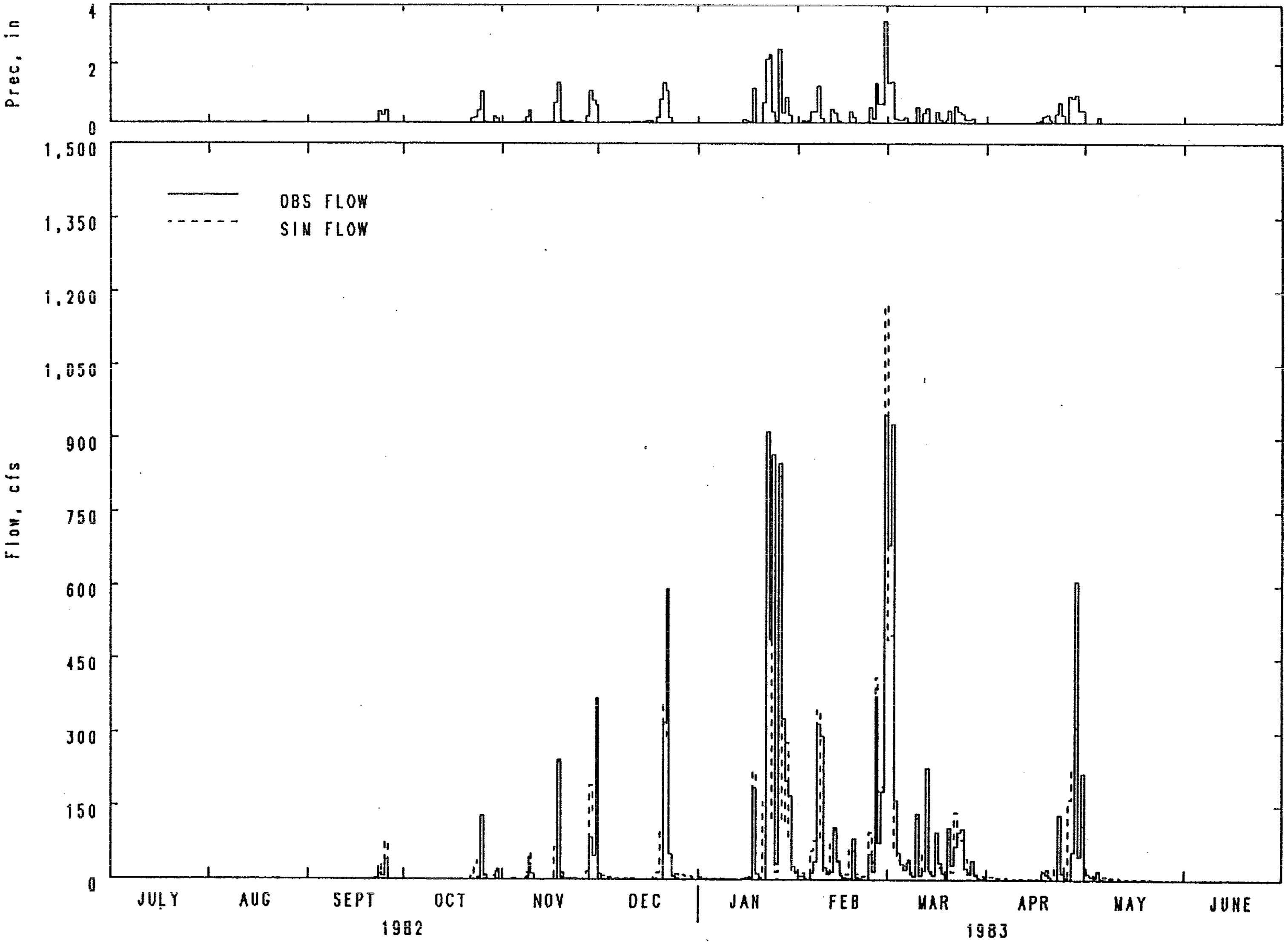
Simulated and Observed Daily Flow at Rainbow Drive, 1982-83
Simulated and Observed Daily Flow at Rainbow Drive, 1983-84
Simulated and Observed Daily Flow at Rainbow Drive, 1984-85
Simulated and Observed Daily Flow at Rainbow Drive, 1985-86
Simulated and Observed Daily Flow at Rainbow Drive, 1986-87
Simulated and Observed Daily Flow at Rainbow Drive, 1987-88
Simulated and Observed Daily Flow at Rainbow Drive, 1988-89
Simulated and Observed Daily Flow at Rainbow Drive, 1989-90
Simulated and Observed Daily Flow at Rainbow Drive, 1990-91
Simulated and Observed Daily Flow at Rainbow Drive, 1991-92

## Calabazas Creek Hydrology Verification

Simulated and Observed Daily Flow at Wilcox High School, 1972-73
Simulated and Observed Daily Flow at Wilcox High School, 1973-74
Simulated and Observed Daily Flow at Wilcox High School, 1974-75
Simulated and Observed Daily Flow at Wilcox High School, 1975-76
Simulated and Observed Daily Flow at Wilcox High School, 1976-77
Simulated and Observed Daily Flow at Wilcox High School, 1977-78
Simulated and Observed Daily Flow at Wilcox High School, 1978-79
Simulated and Observed Daily Flow at Wilcox High School, 1979-80

Simulated and Observed Daily Flow at Wilcox High School, 1980-81
Simulated and Observed Daily Flow at Wilcox High School, 1981-82

Simulated and Observed Daily Flow at Rainbow Drive, 1972-73
Simulated and Observed Daily Flow at Rainbow Drive, 1973-74
Simulated and Observed Daily Flow at Rainbow Drive, 1974-75
Simulated and Observed Daily Flow at Rainbow Drive, 1975-76
Simulated and Observed Daily Flow at Rainbow Drive, 1976-77
Simulated and Observed Daily Flow at Rainbow Drive, 1977-78
Simulated and Observed Daily Flow at Rainbow Drive, 1978-79
Simulated and Observed Daily Flow at Rainbow Drive, 1979-80
Simulated and Observed Daily Flow at Rainbow Drive, 1980-81
Simulated and Observed Daily Flow at Rainbow Drive, 1981-82



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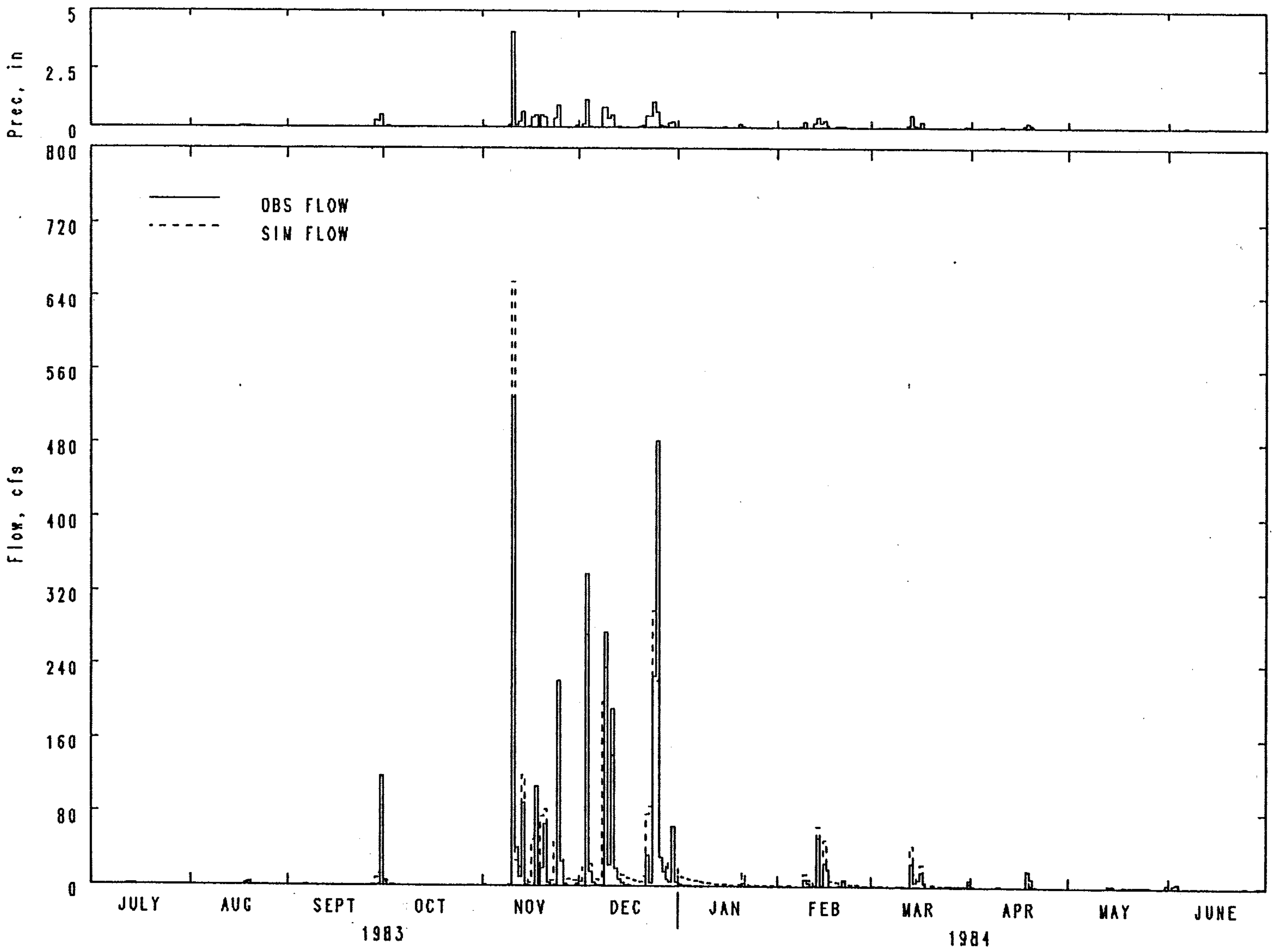
Simulated and Observed Daily Flow at Wilcox High School, 1982-83



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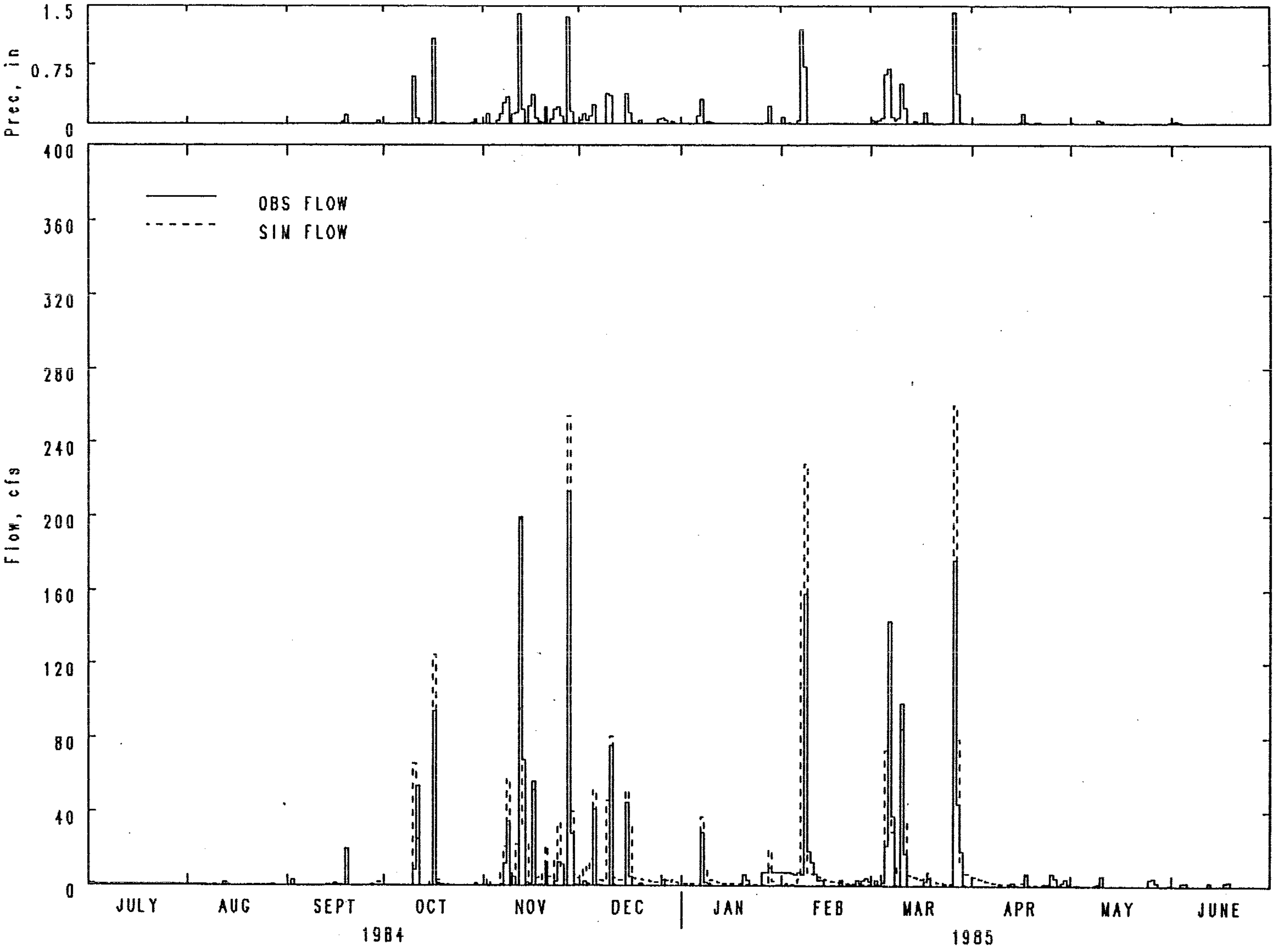

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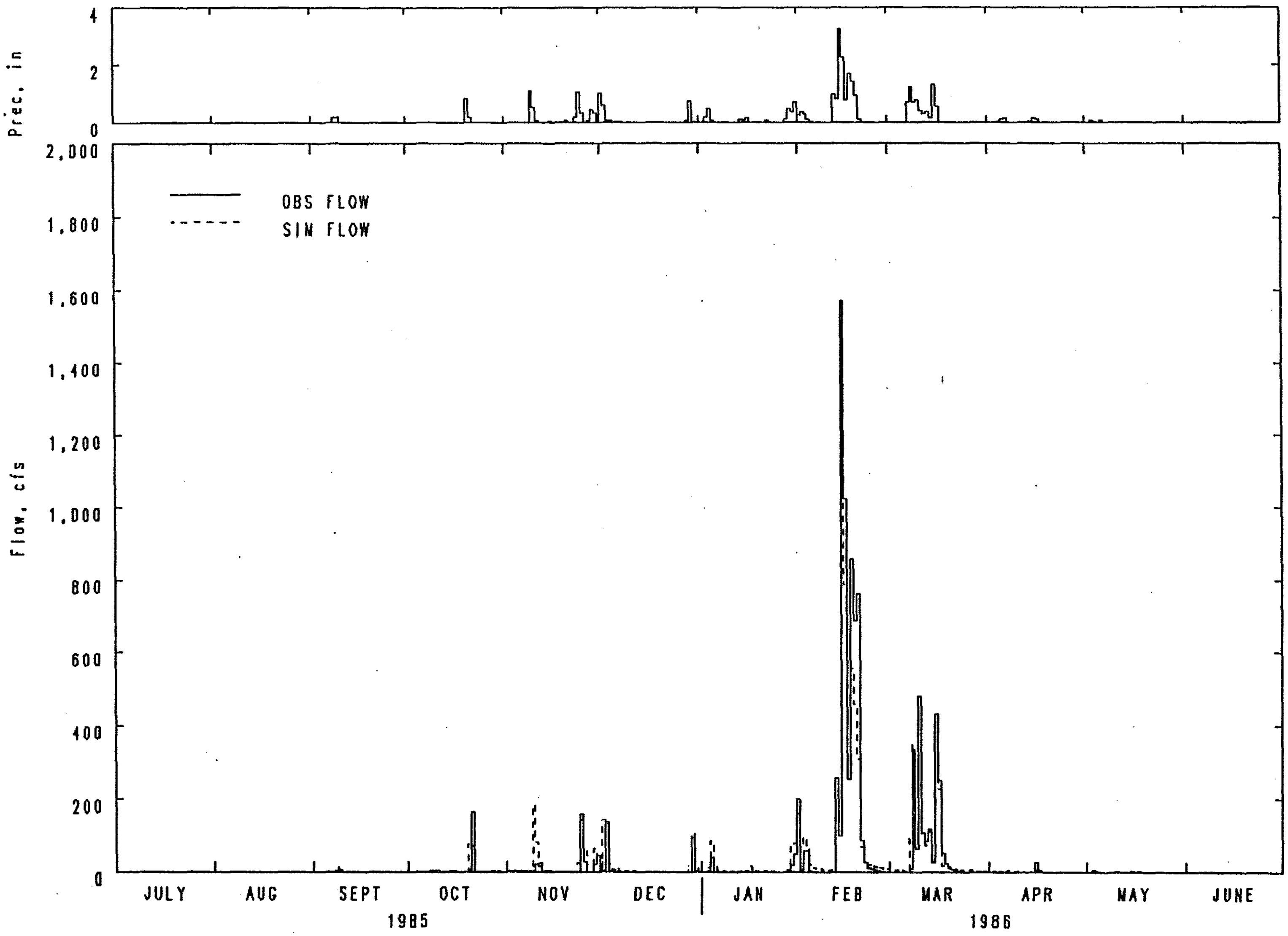

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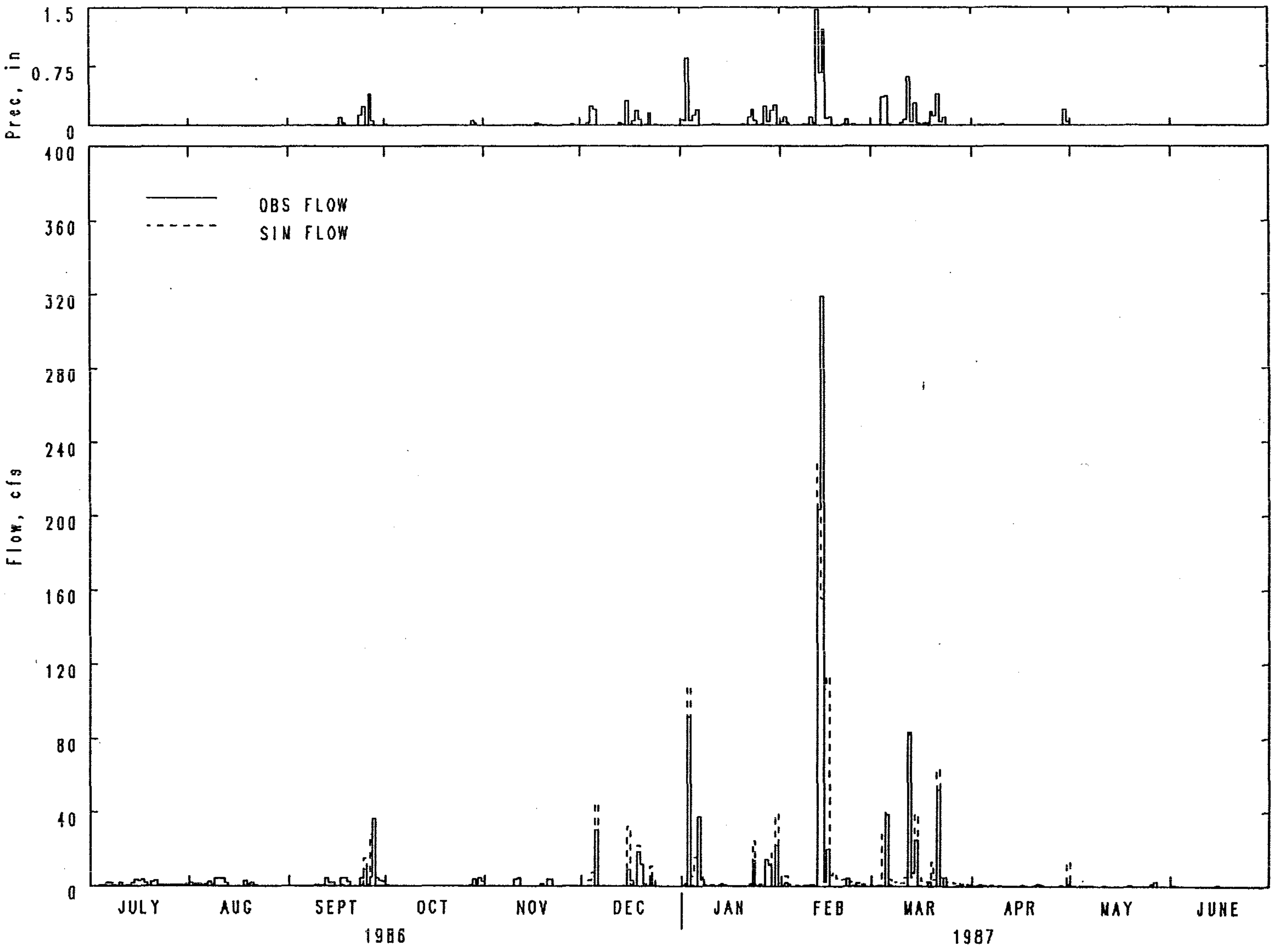

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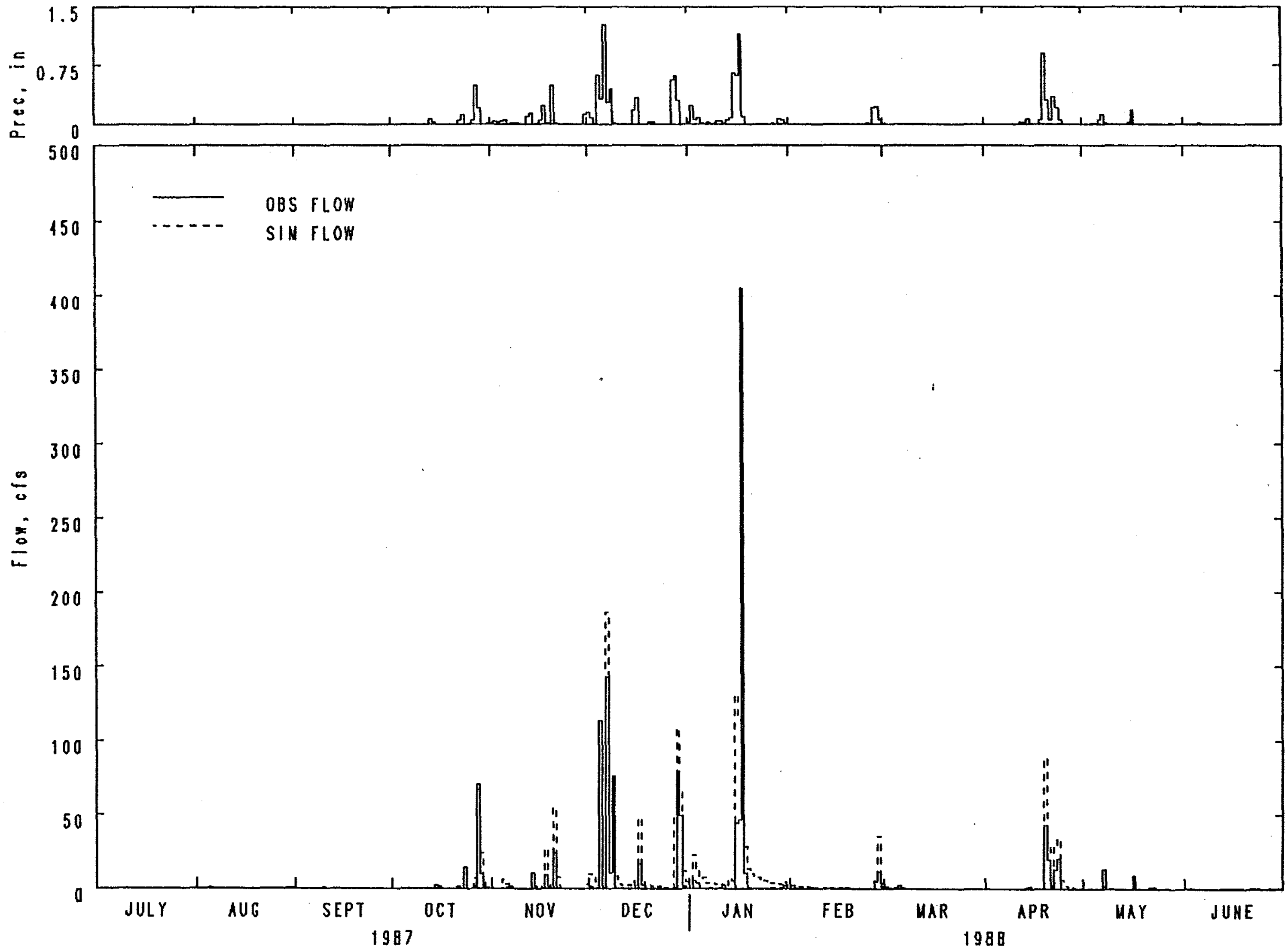
Simulated and Observed Daily Flow at Wilcox High School, 1986-87



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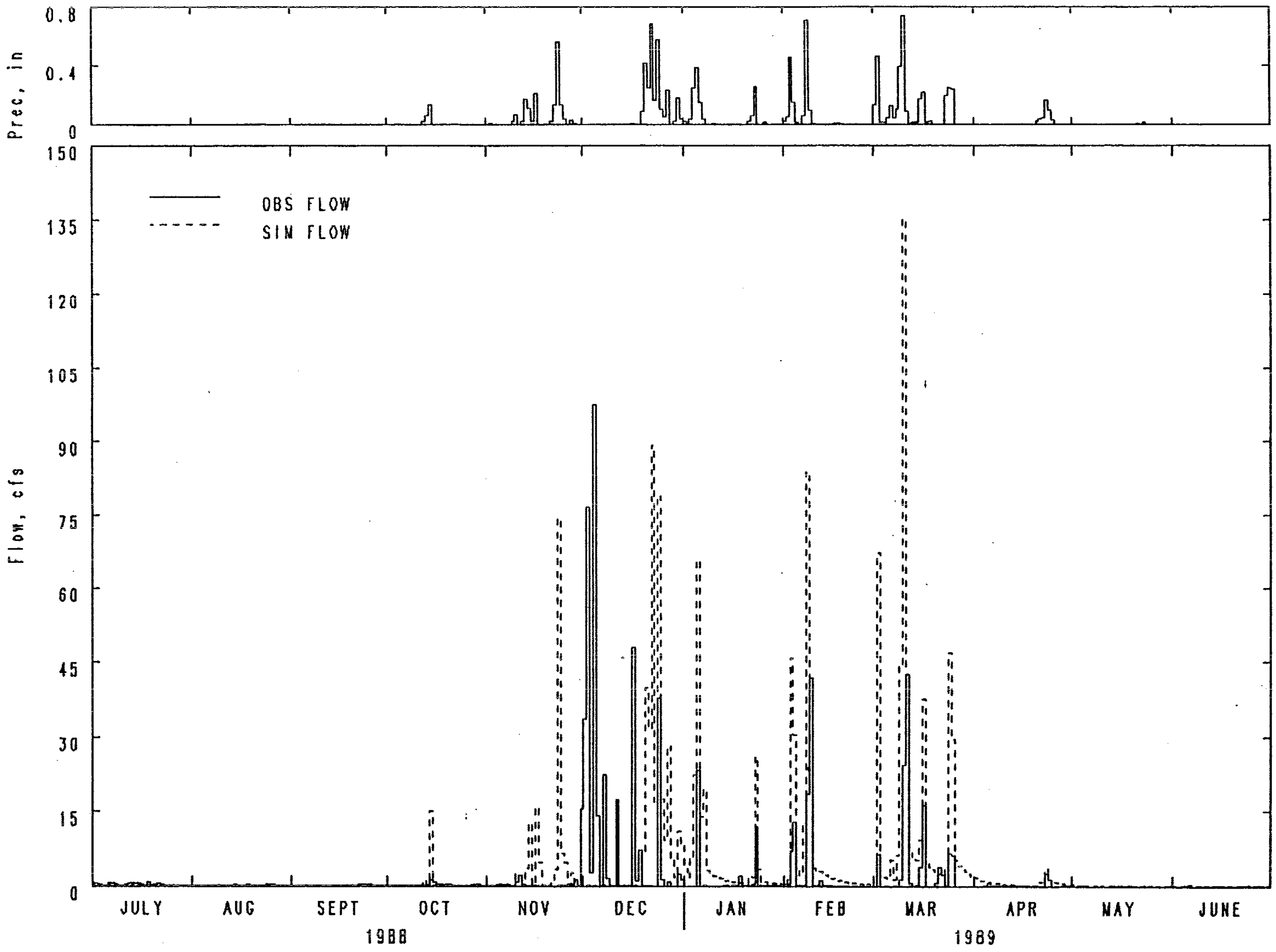

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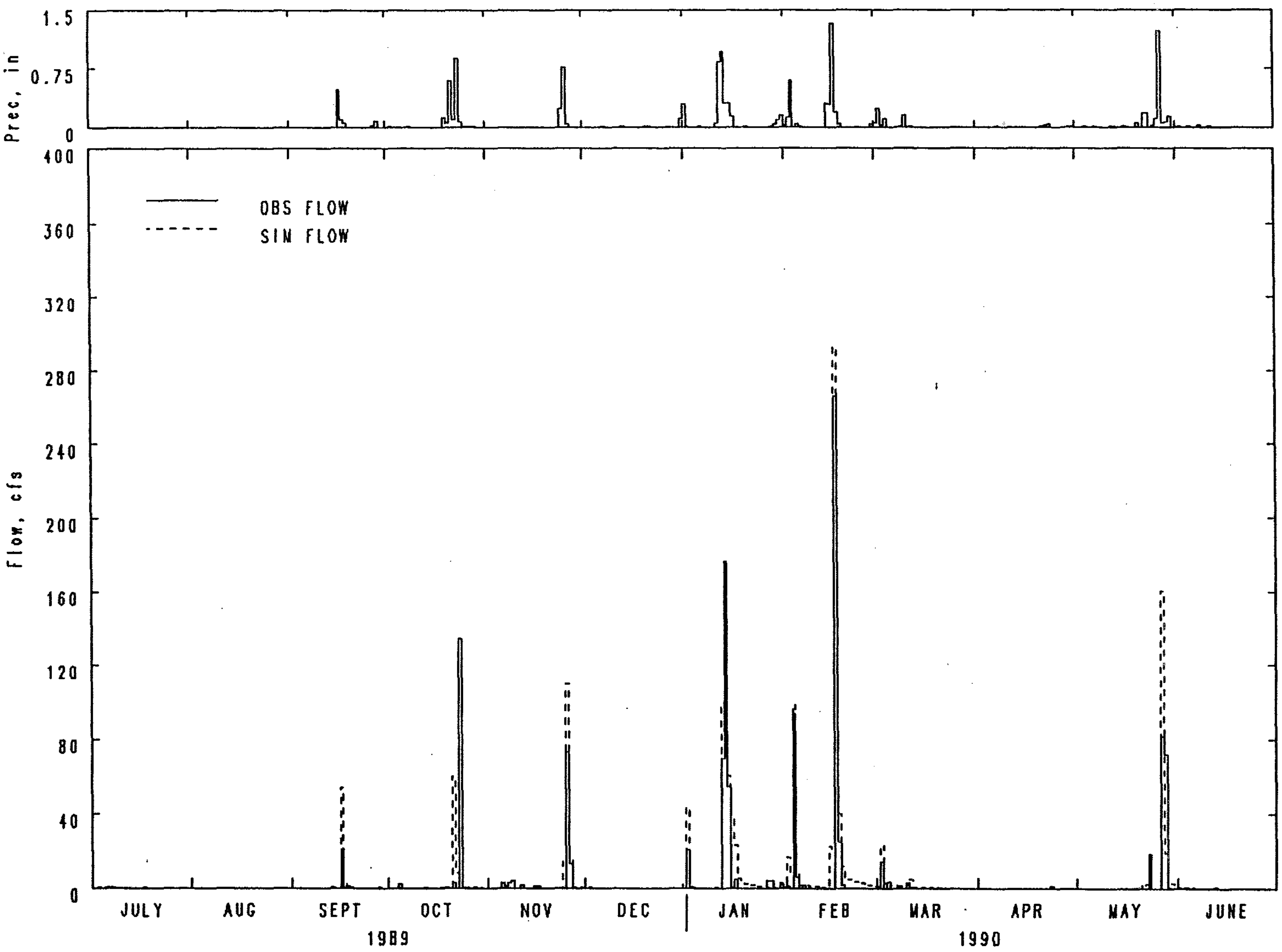

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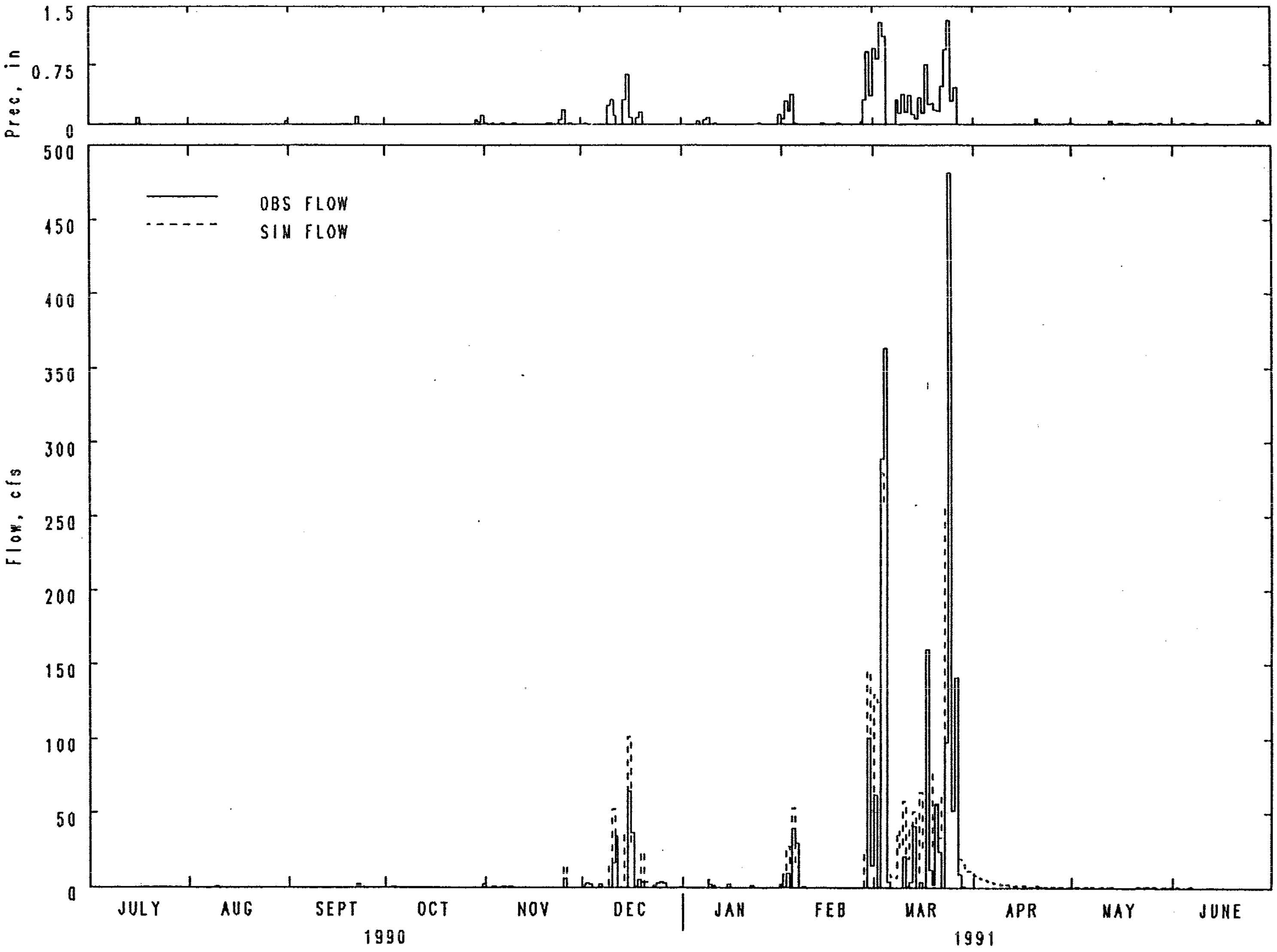

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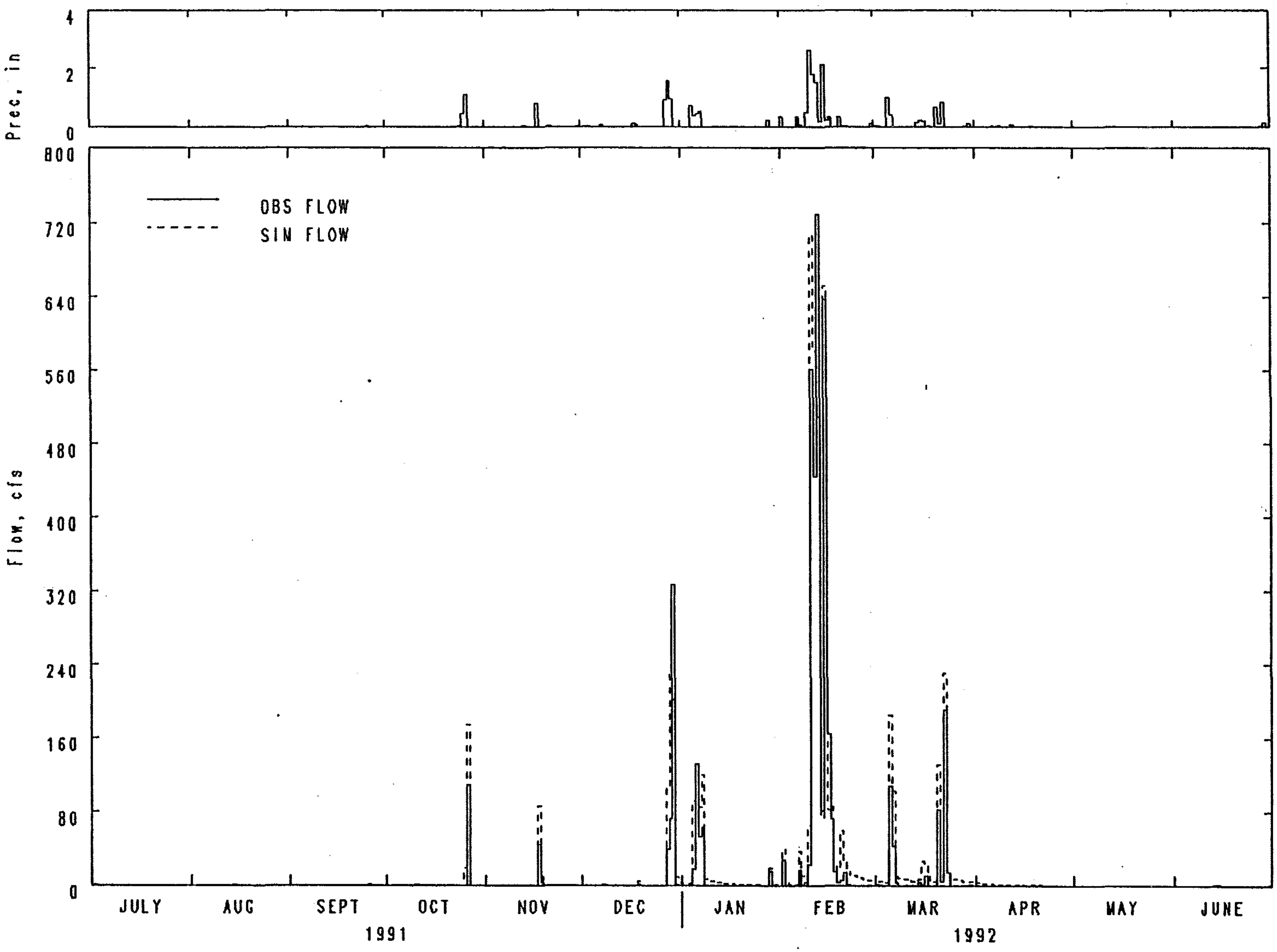

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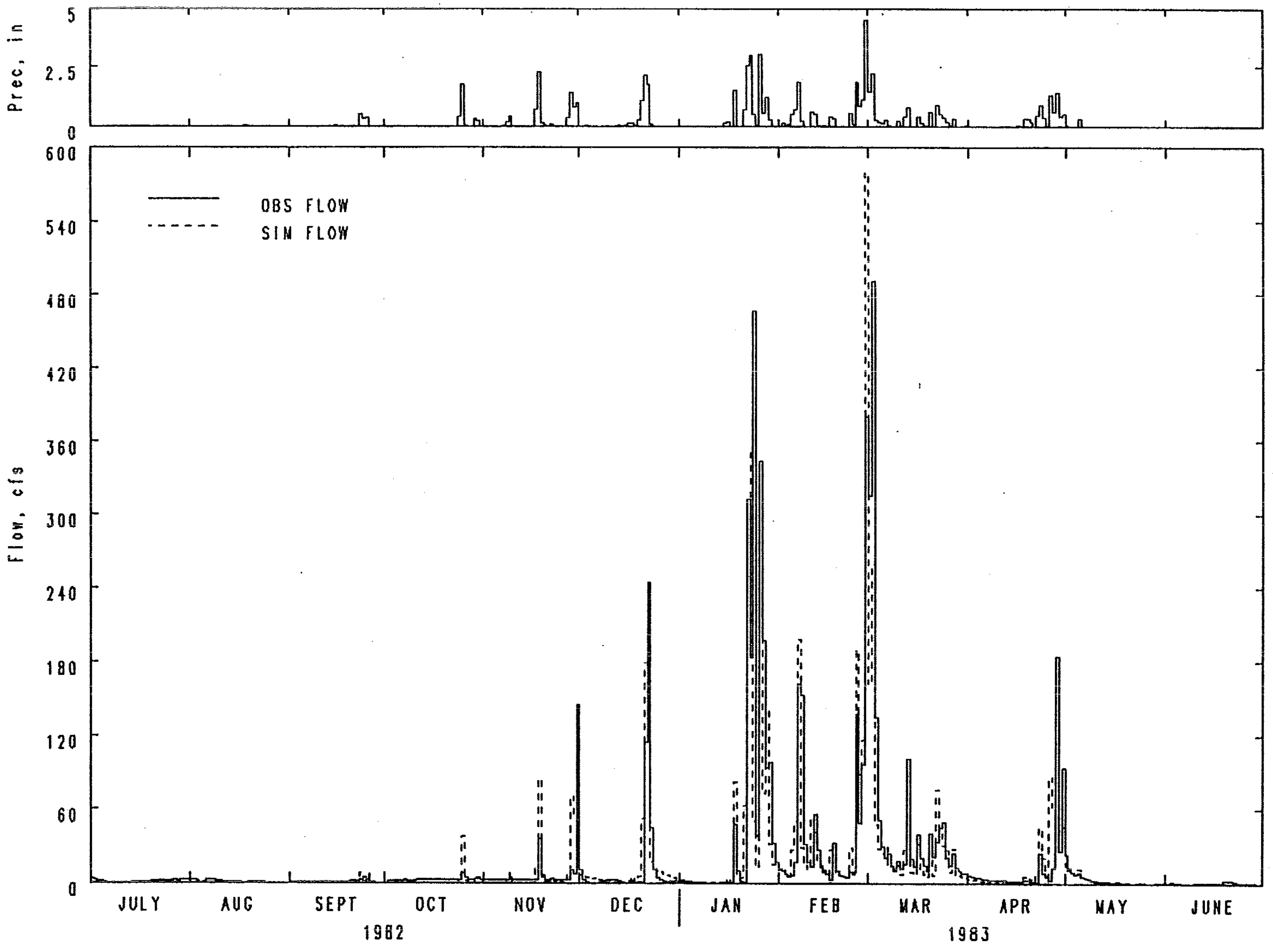

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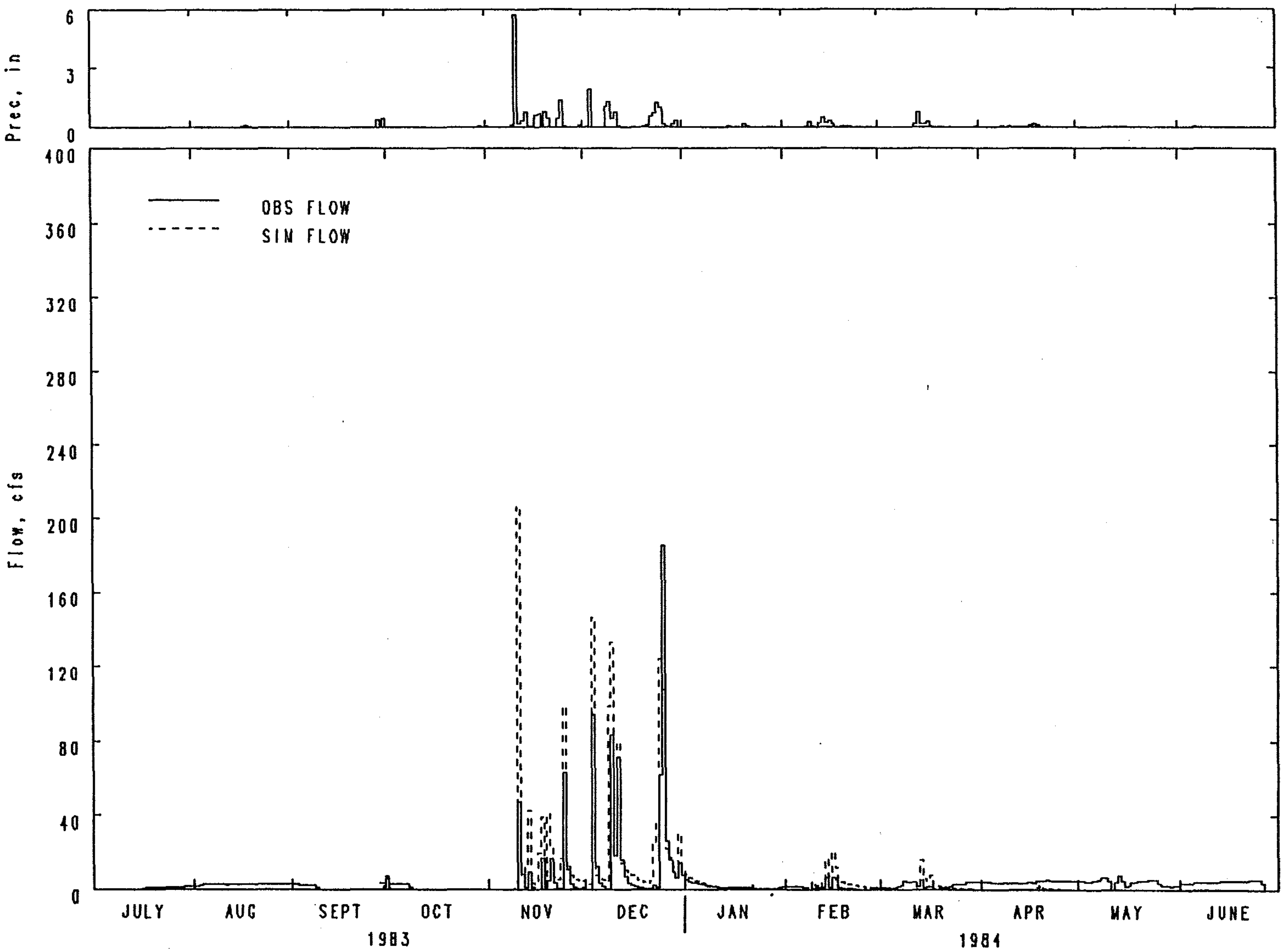
Simulated and Observed Daily Flow at Rainbow Drive, 1982-83



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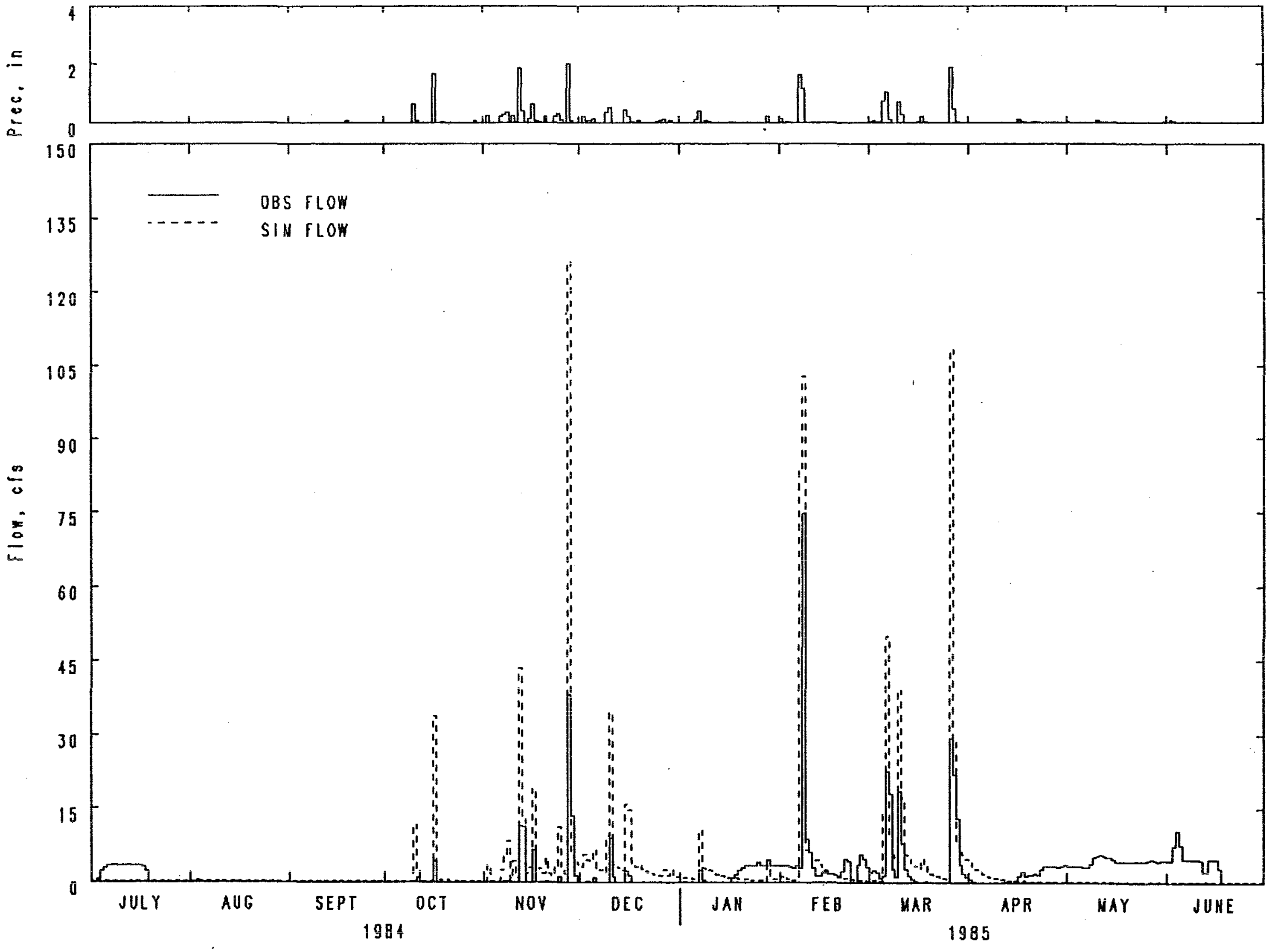

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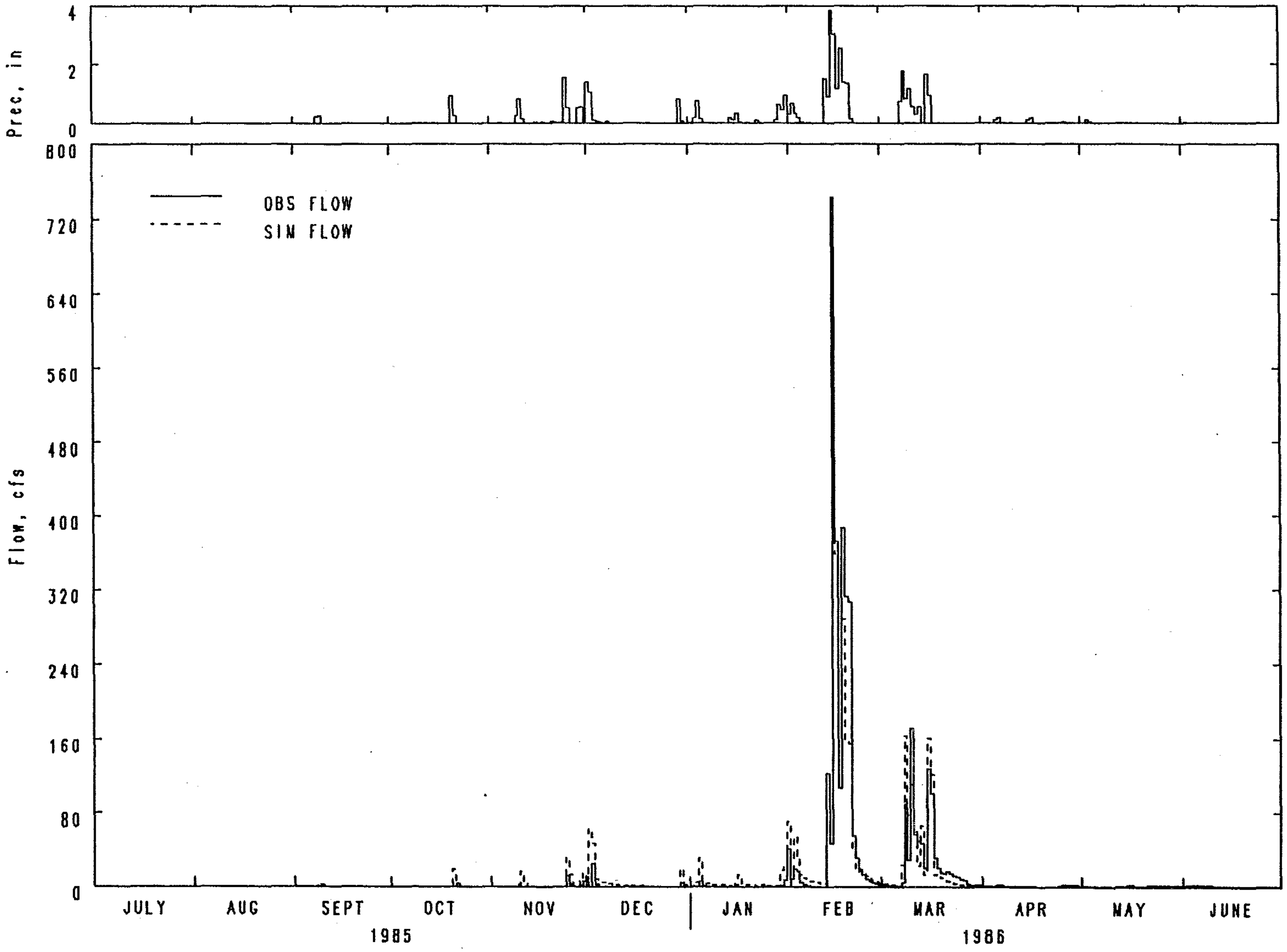

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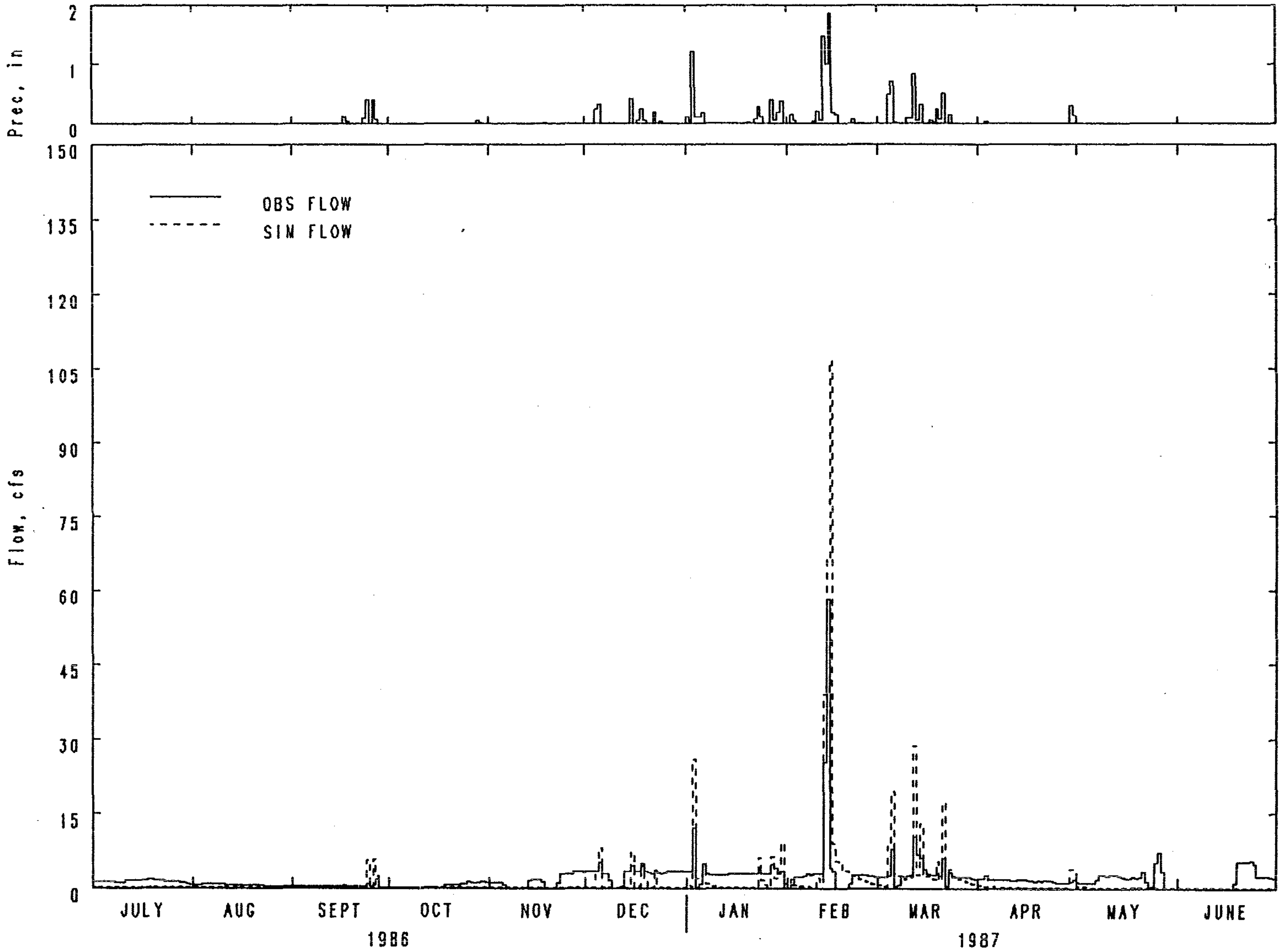

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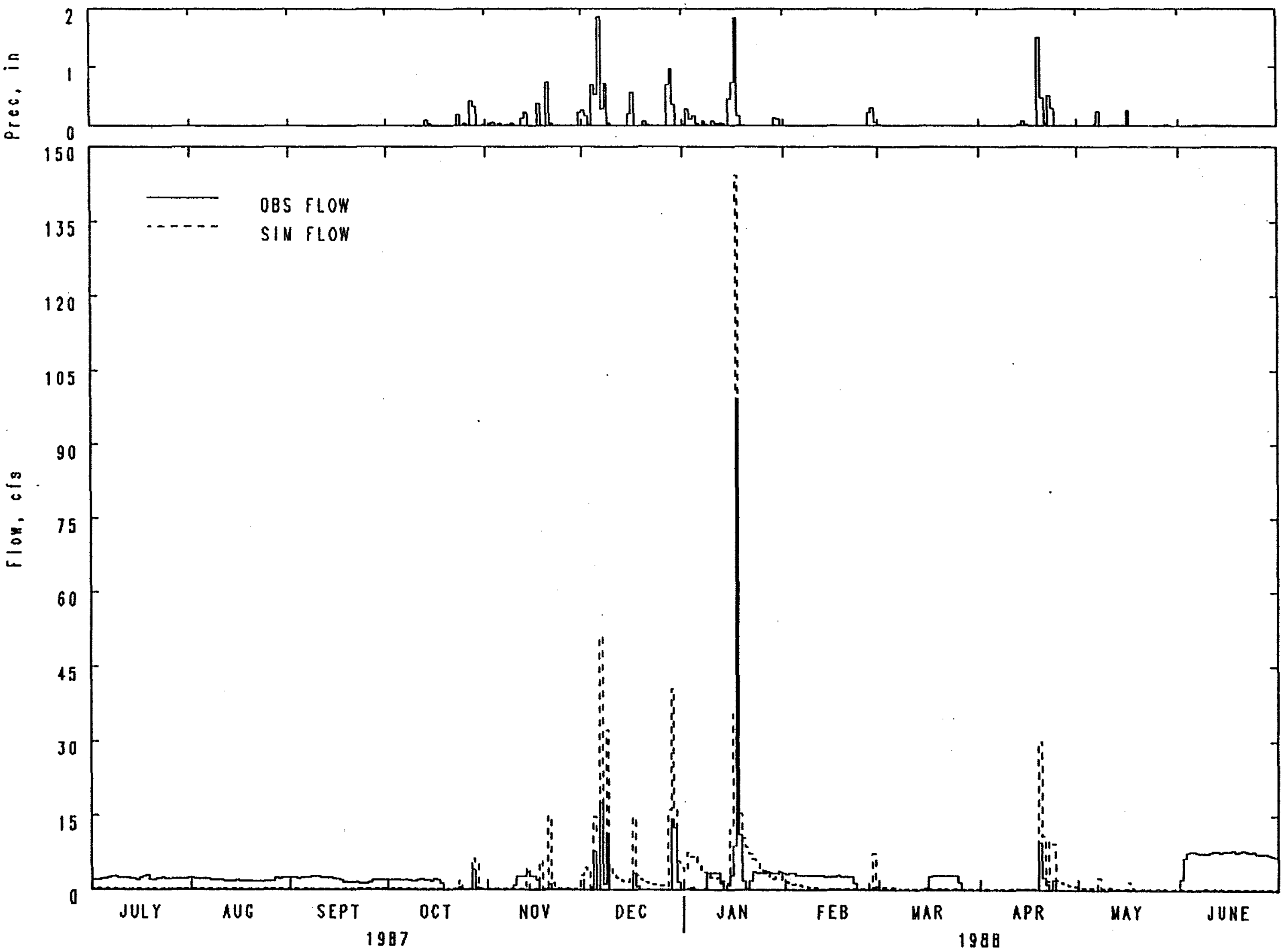

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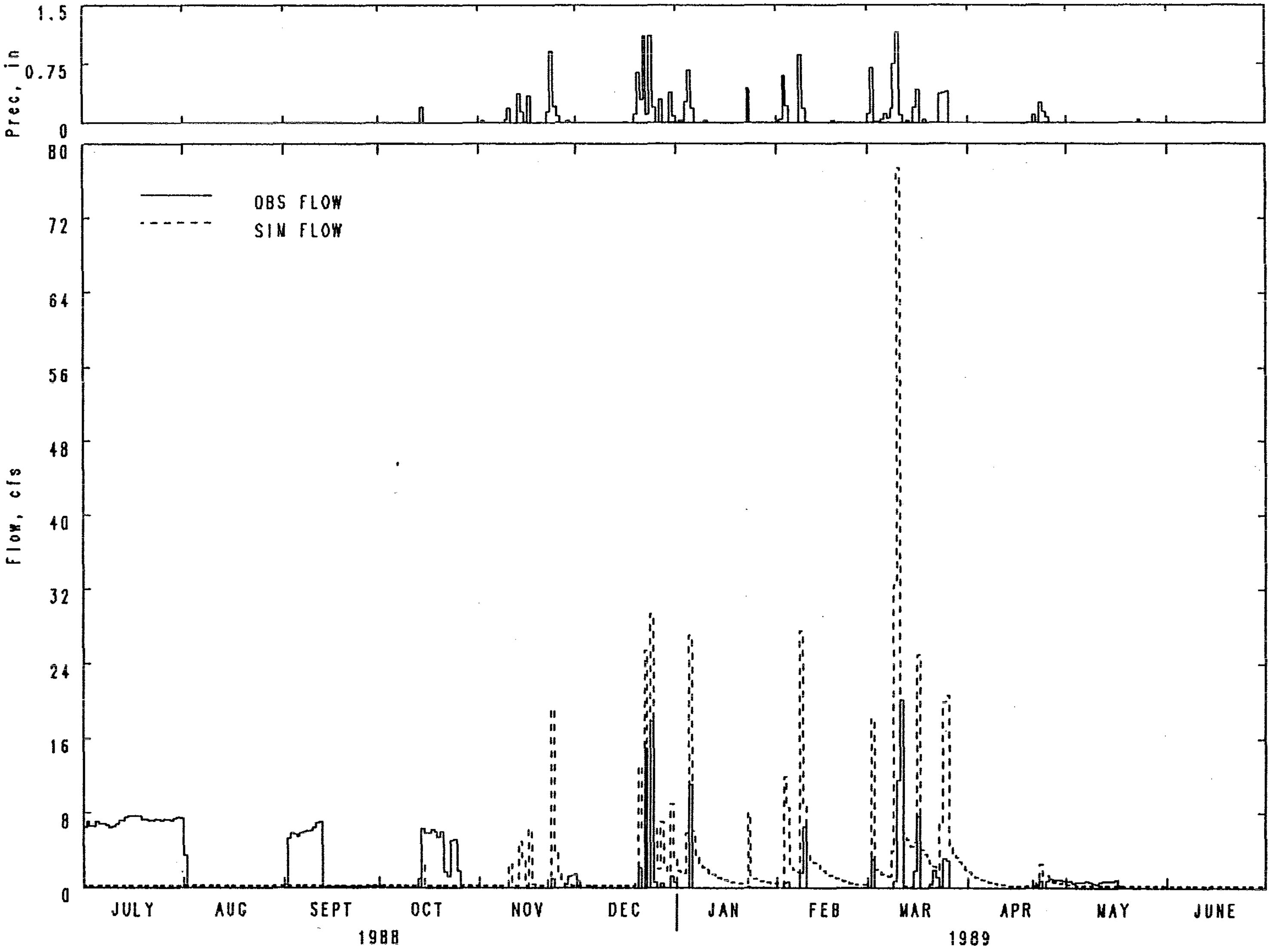

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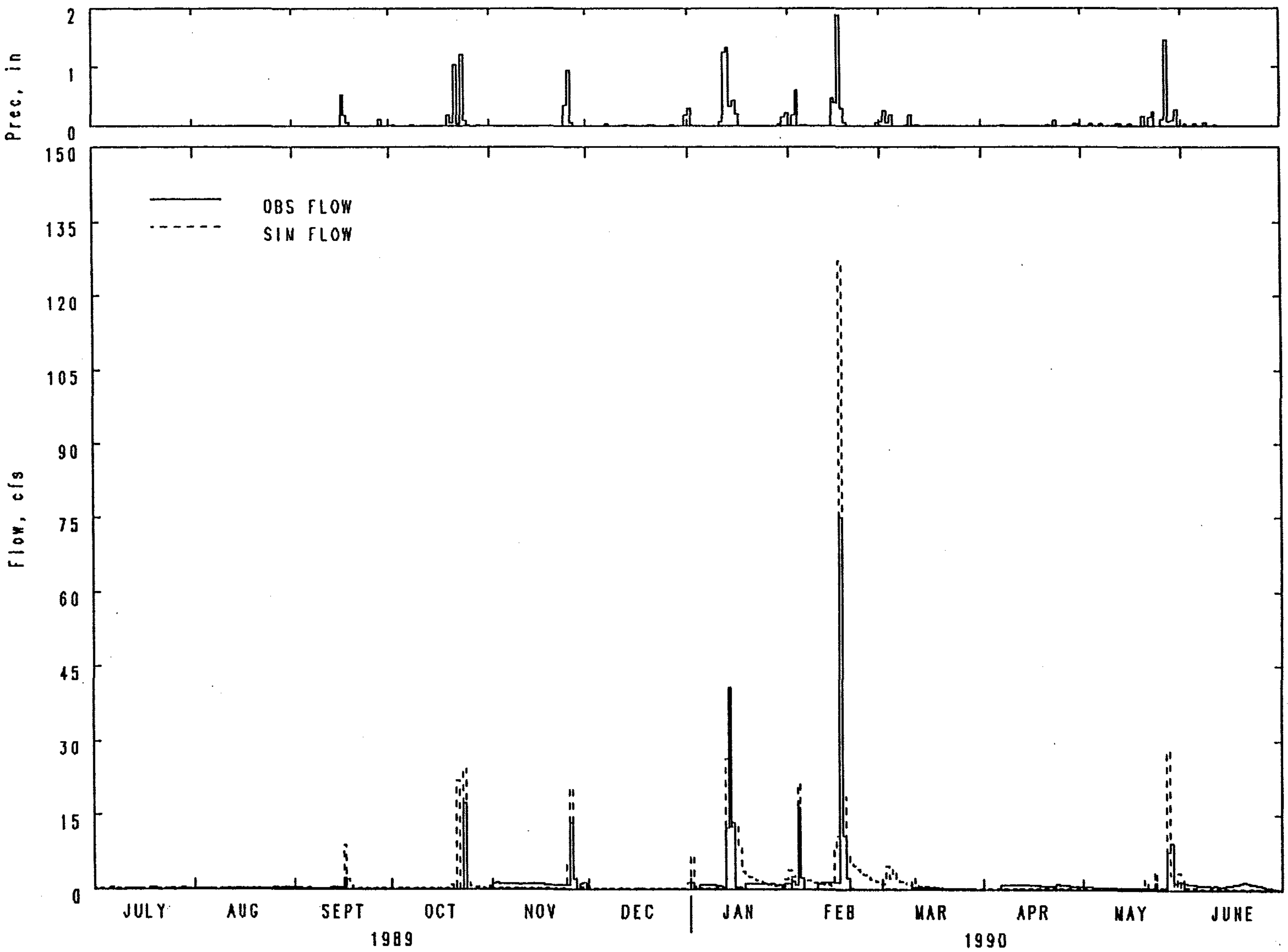

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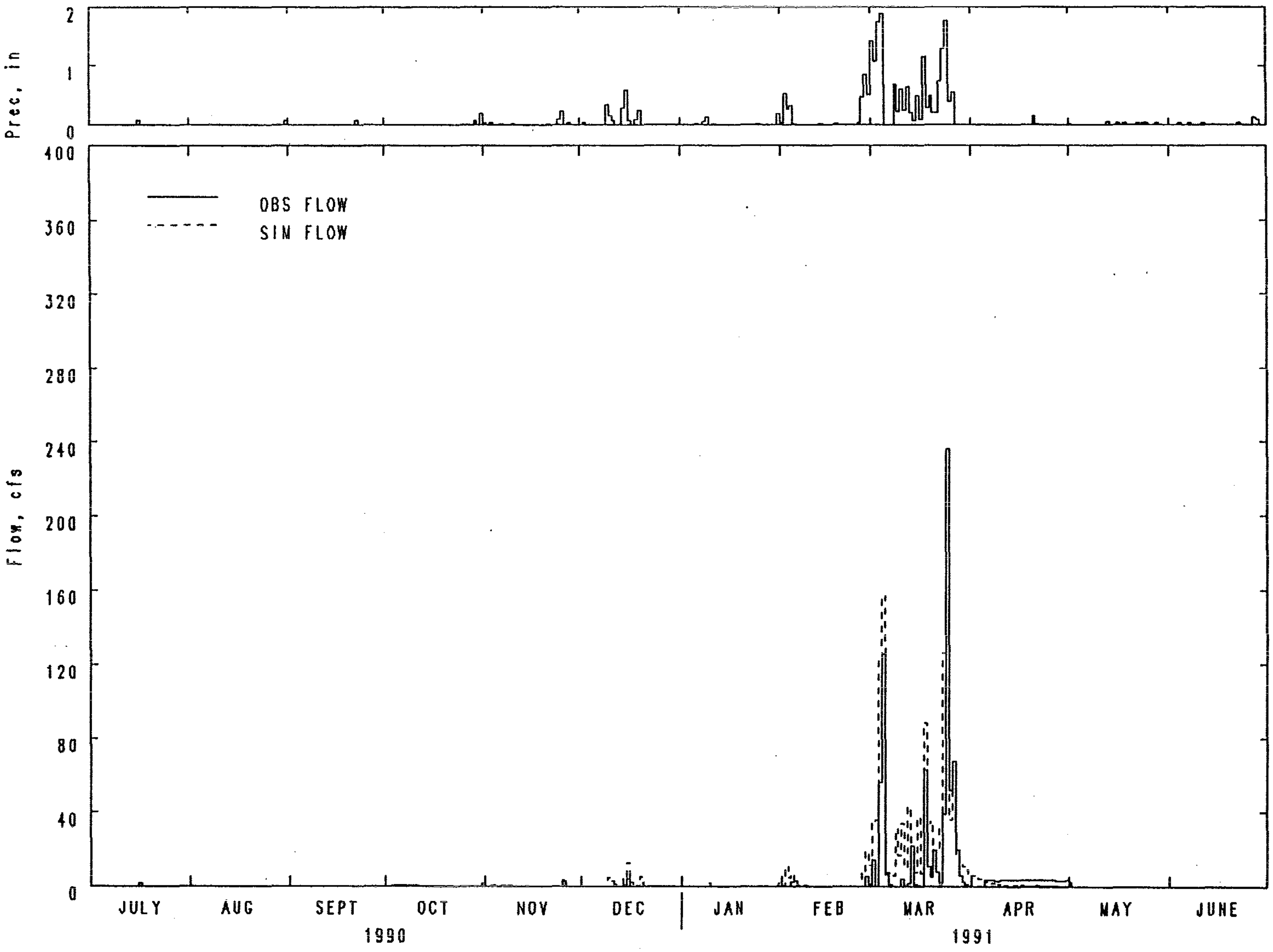
Simulated and Observed Daily Flow at Rainbow Drive, 1989-90



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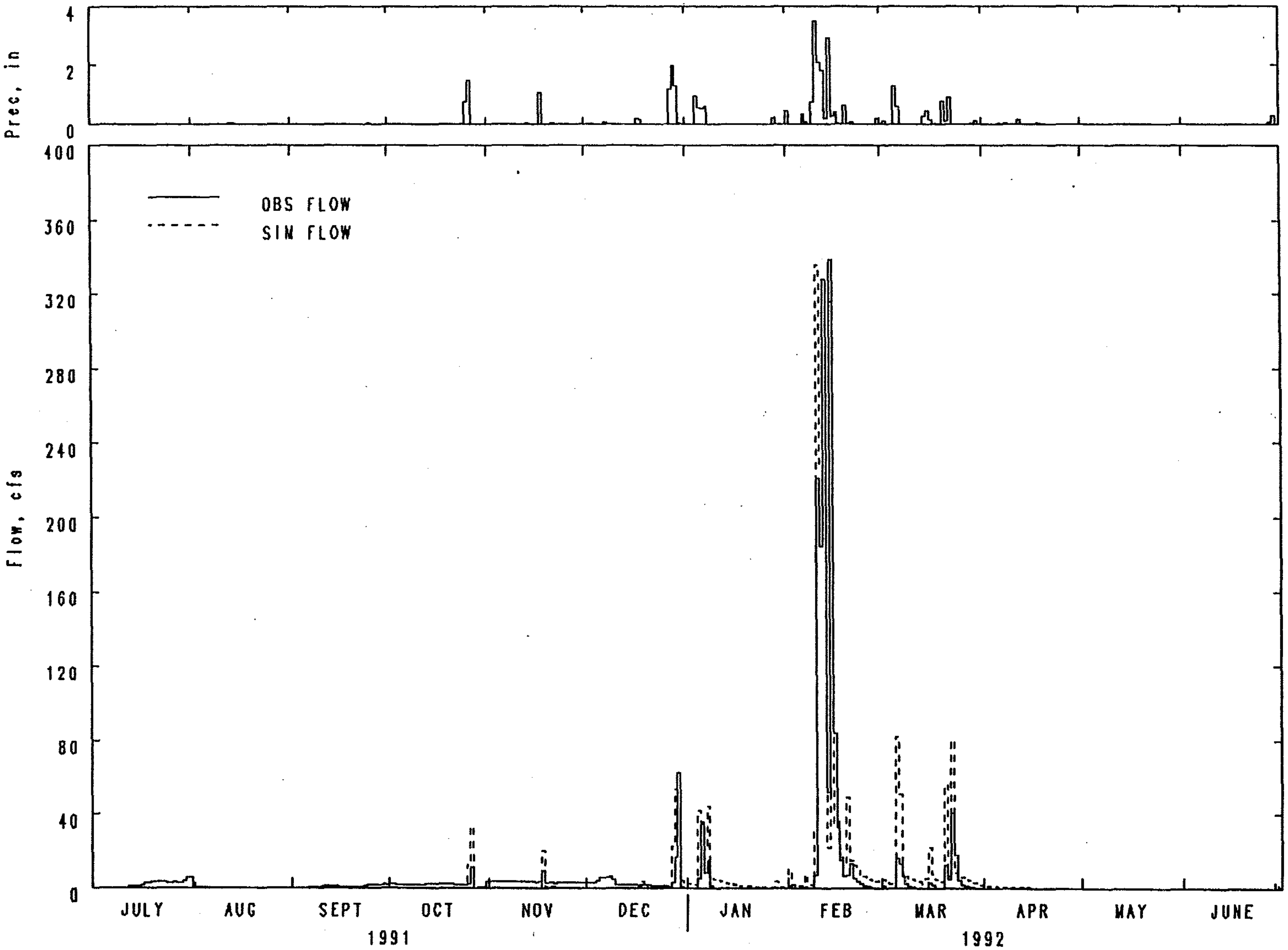
Simulated and Observed Daily Flow at Rainbow Drive, 1990-91



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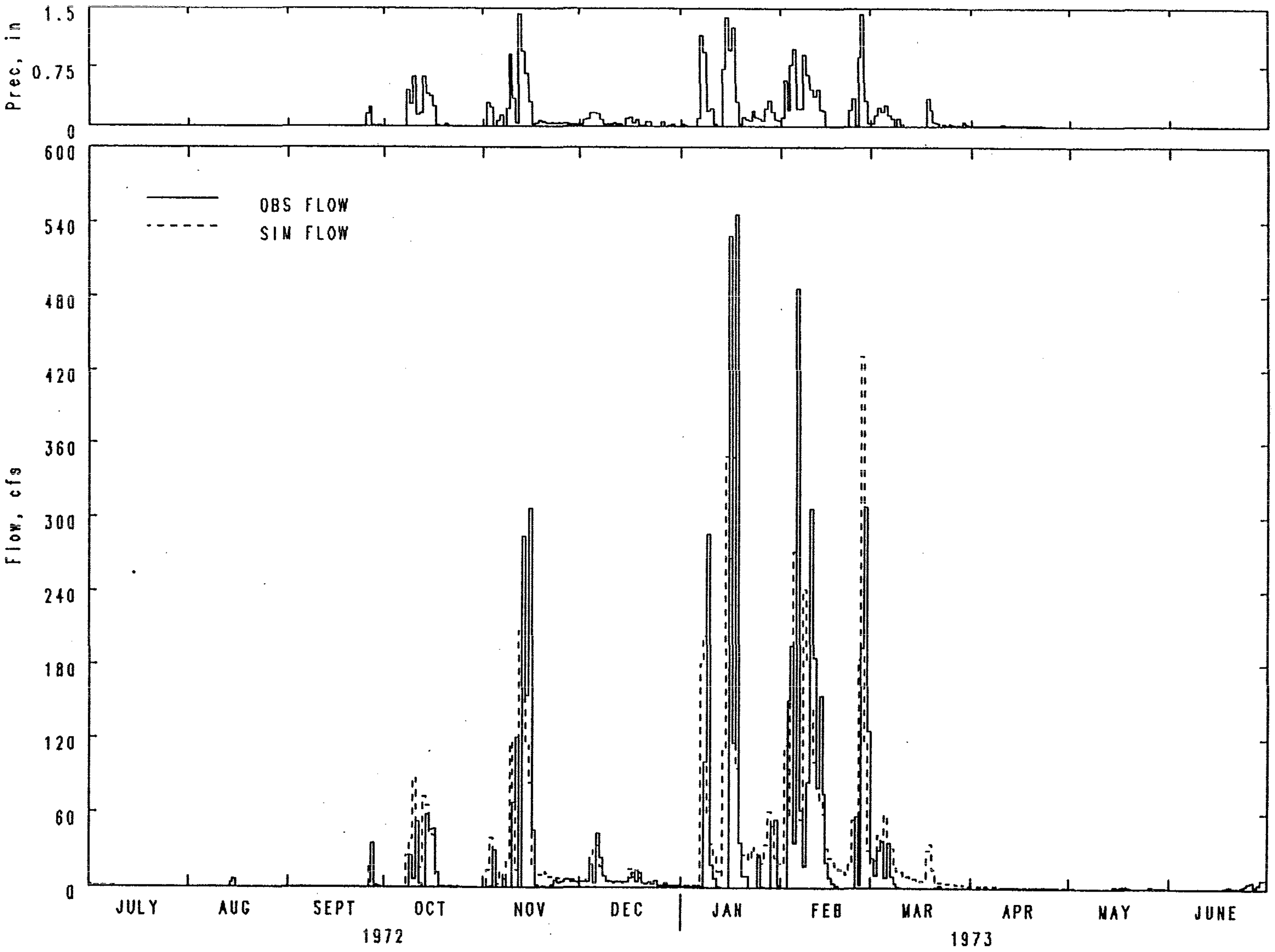
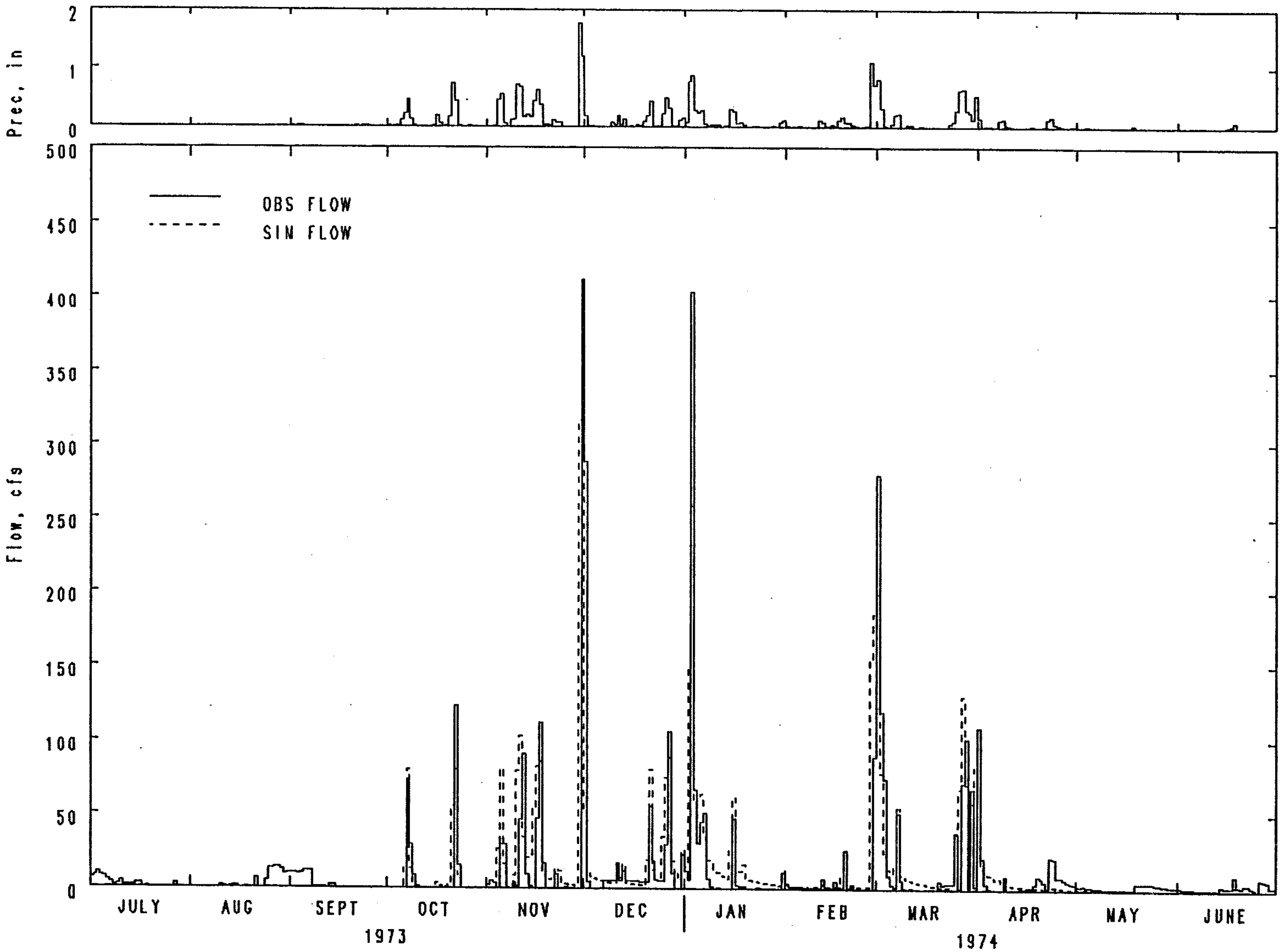
Simulated and Observed Daily Flow at Rainbow Drive, 1991-92



Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Wilcox High School, 1972-73



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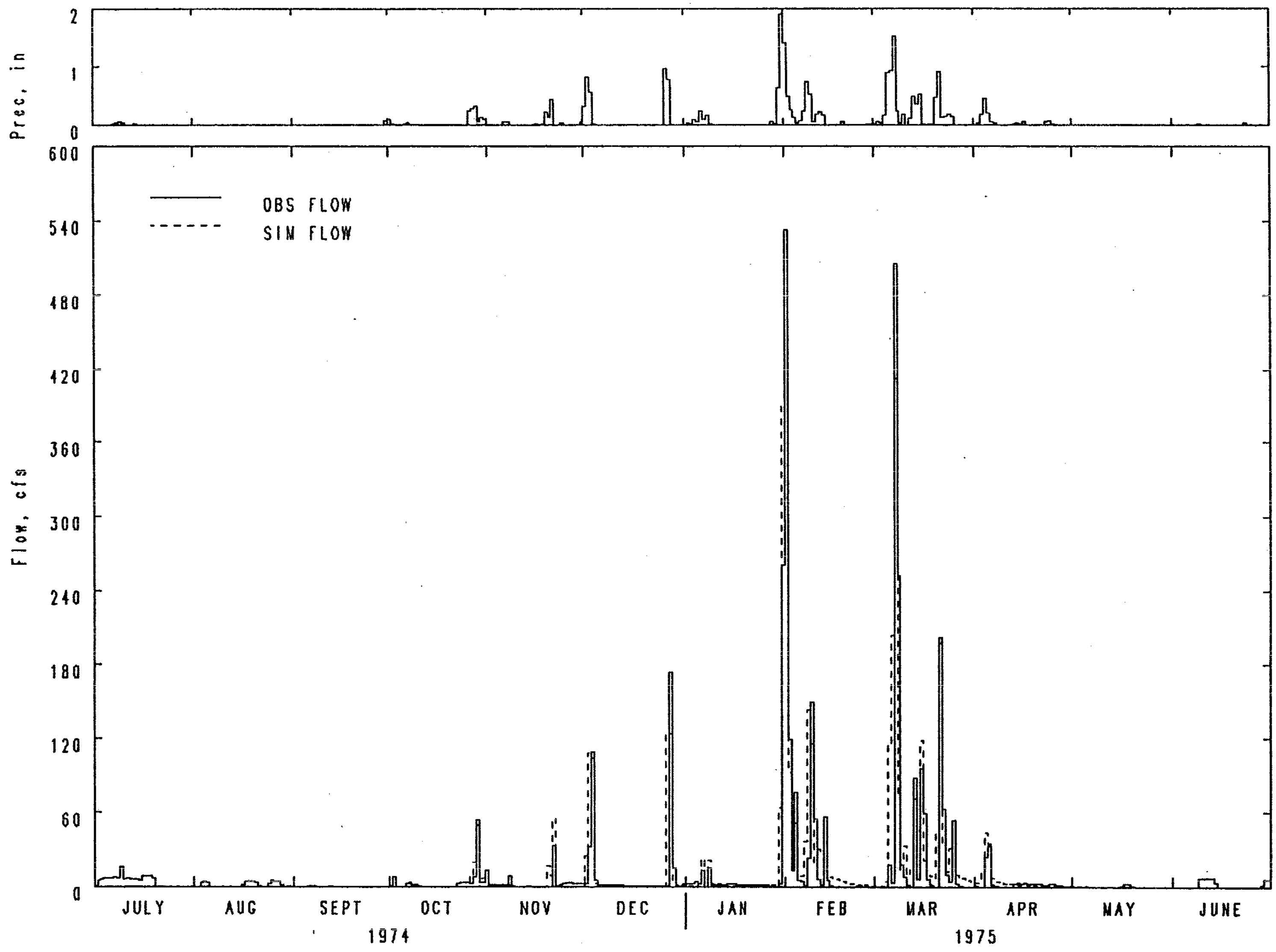

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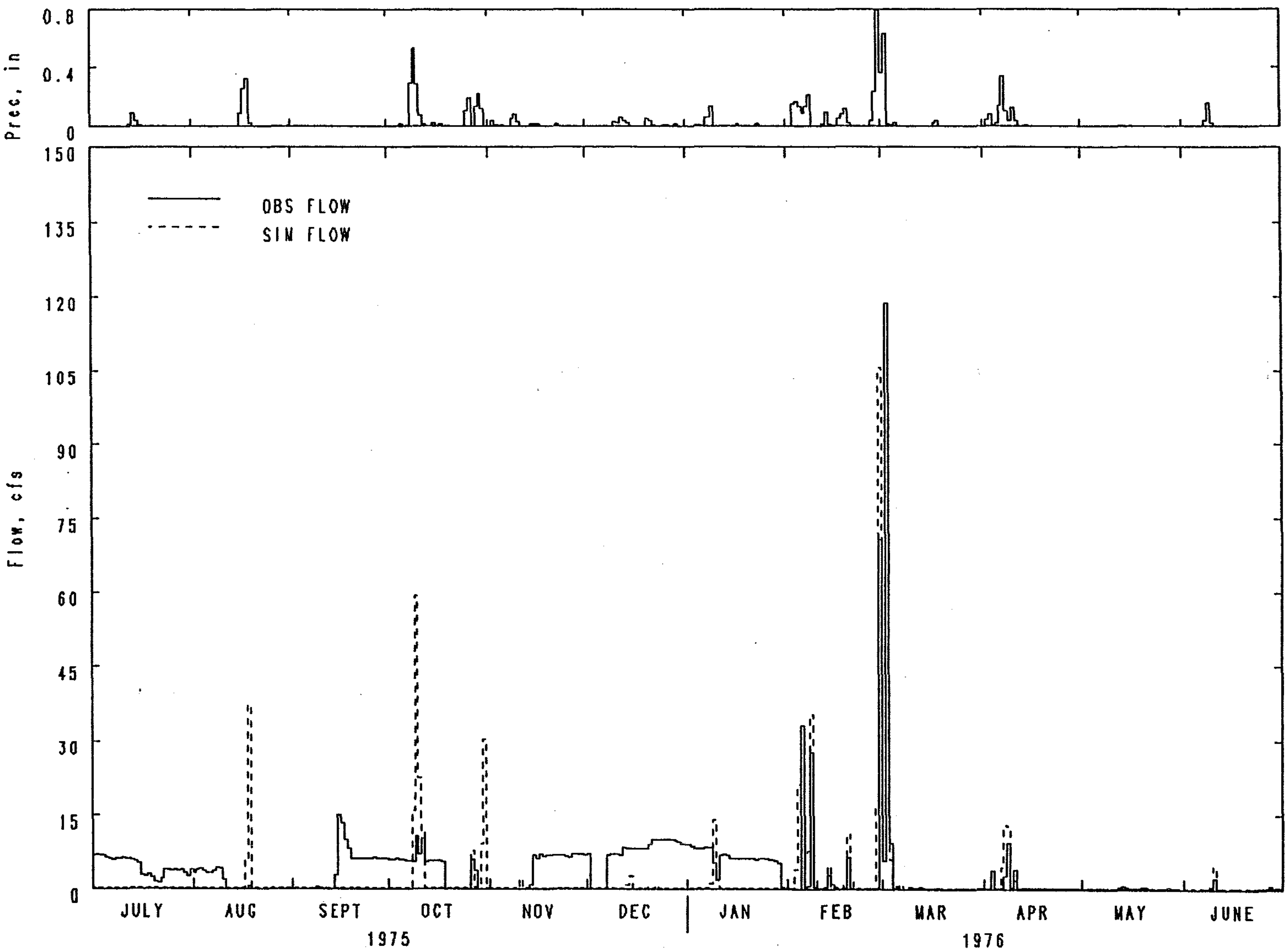

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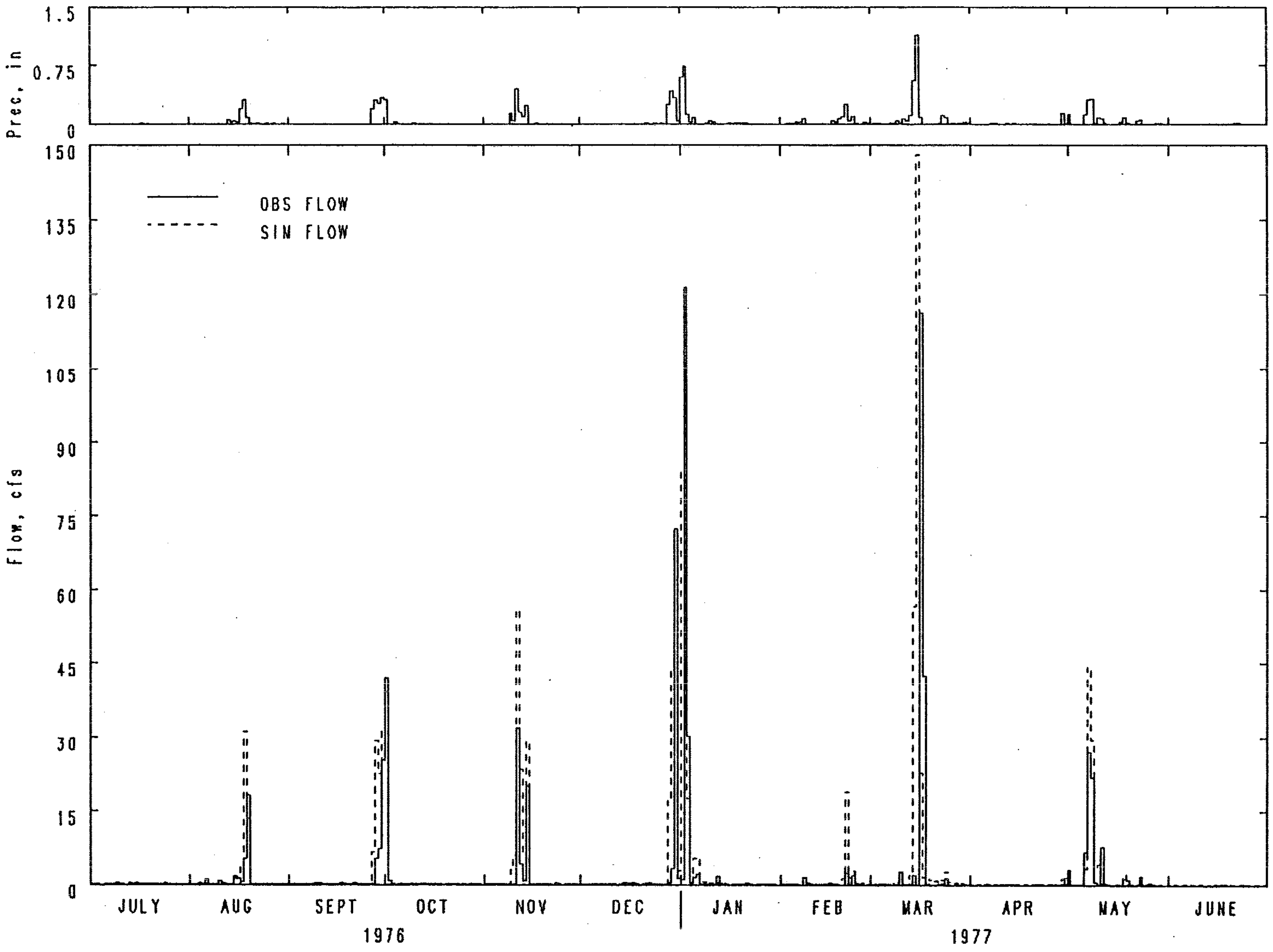

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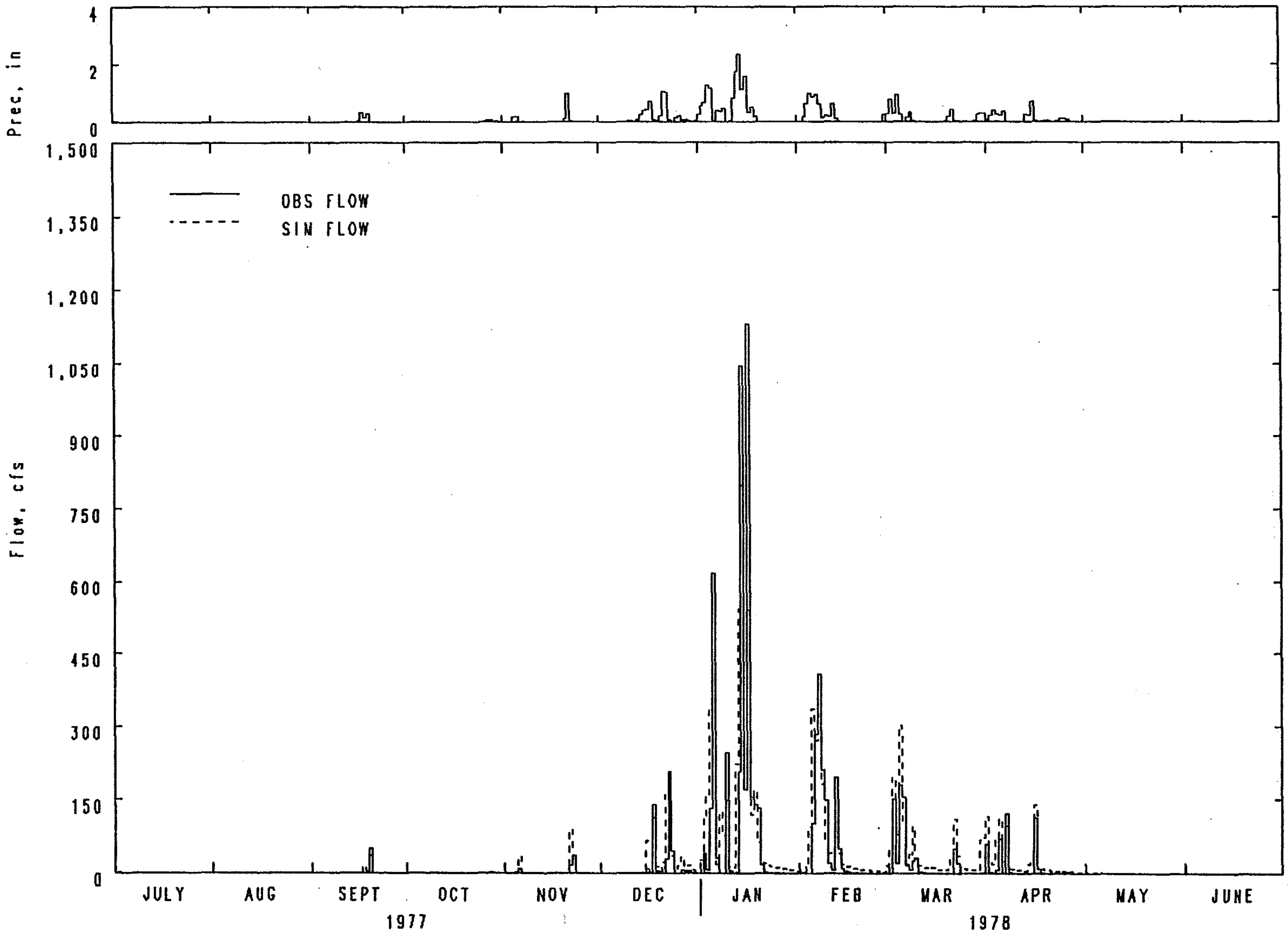

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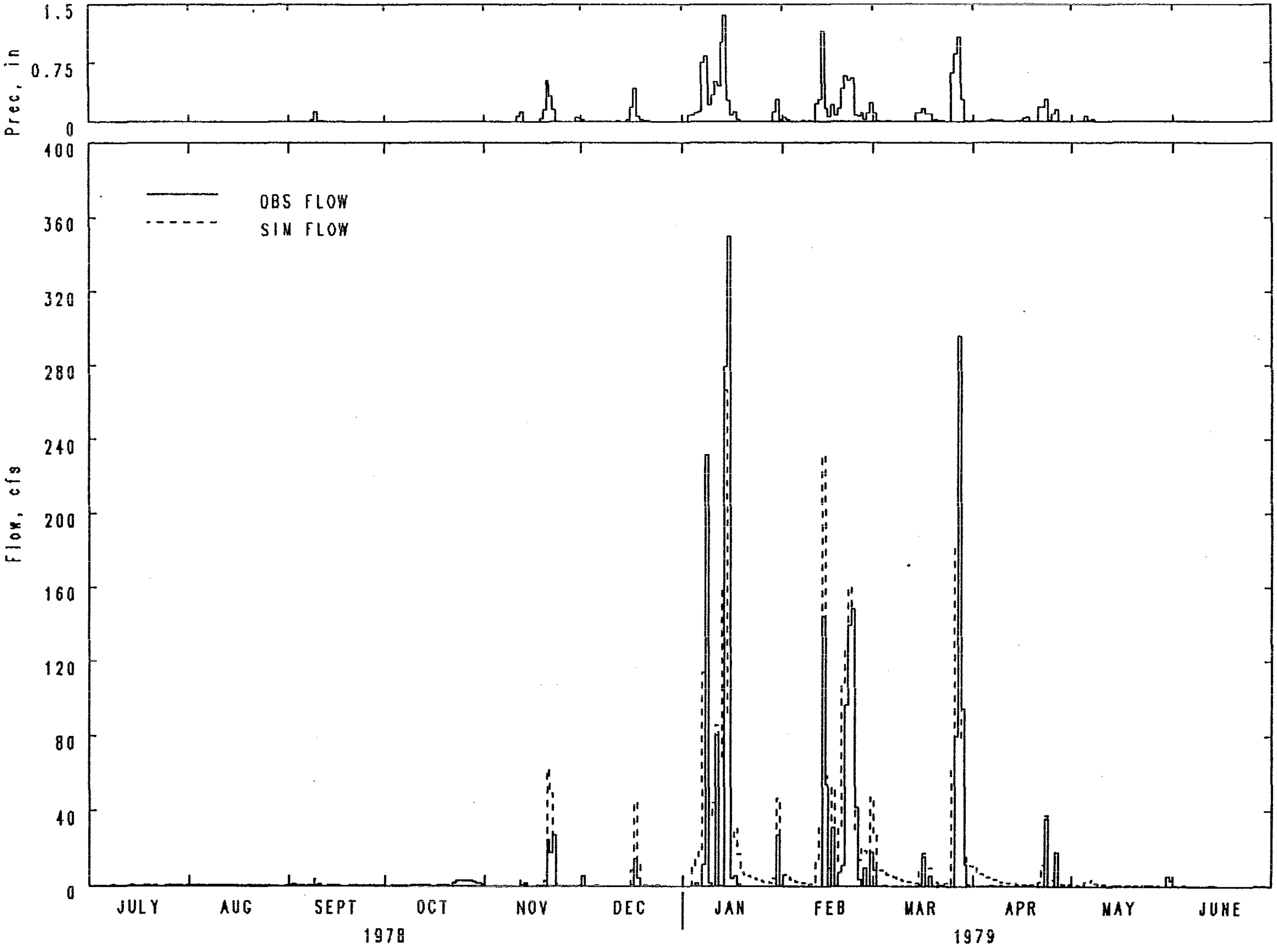

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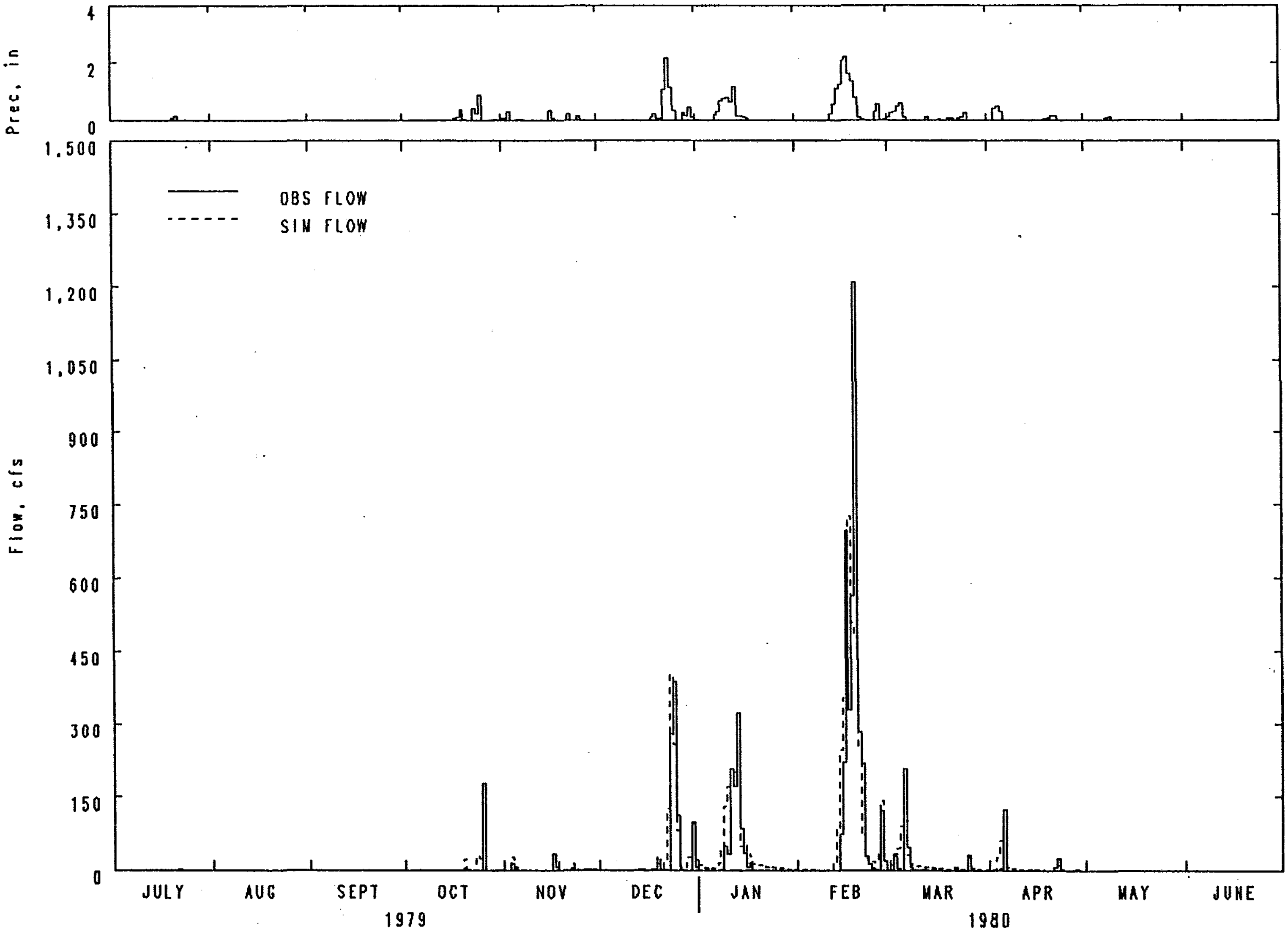

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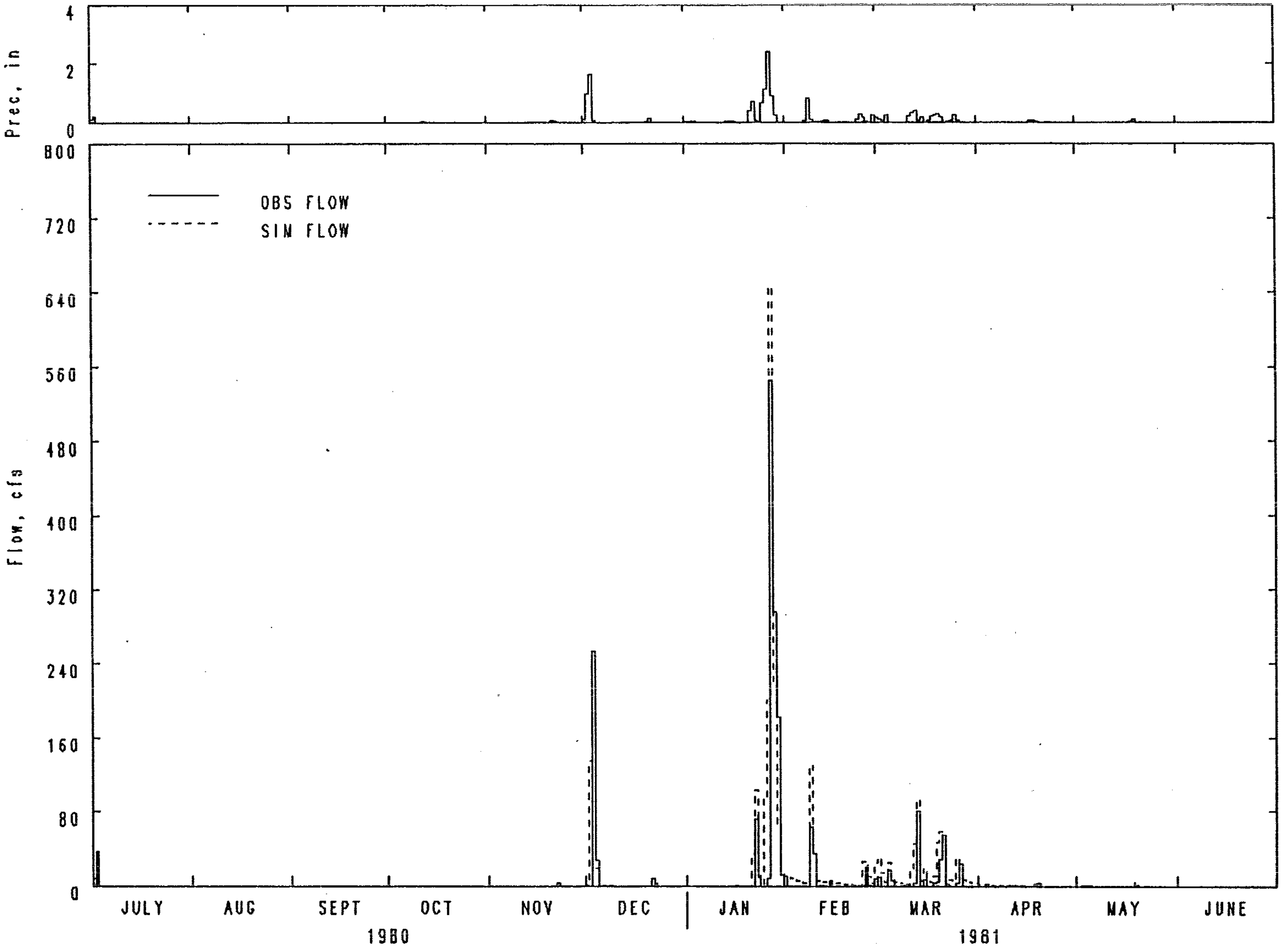

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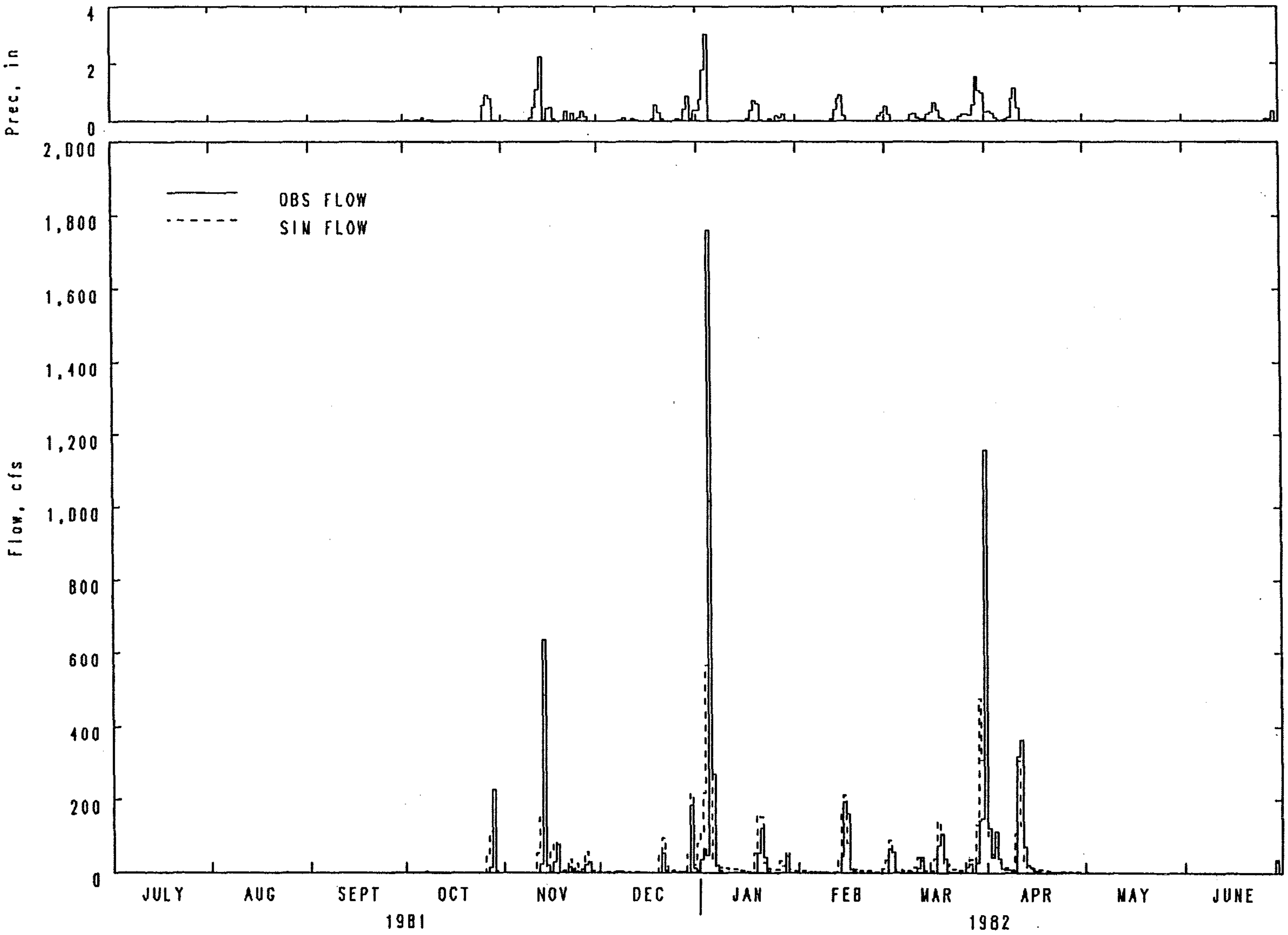

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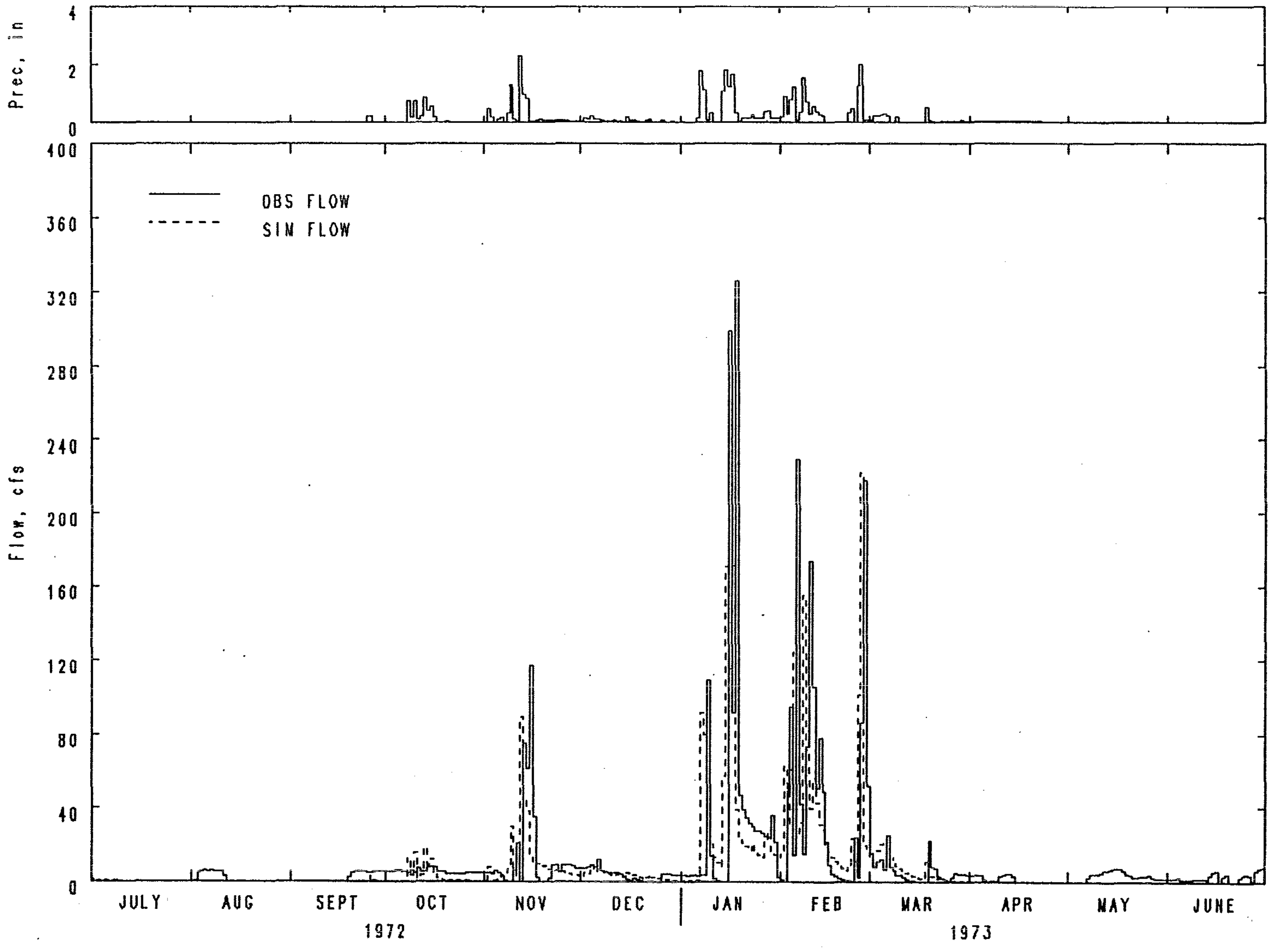

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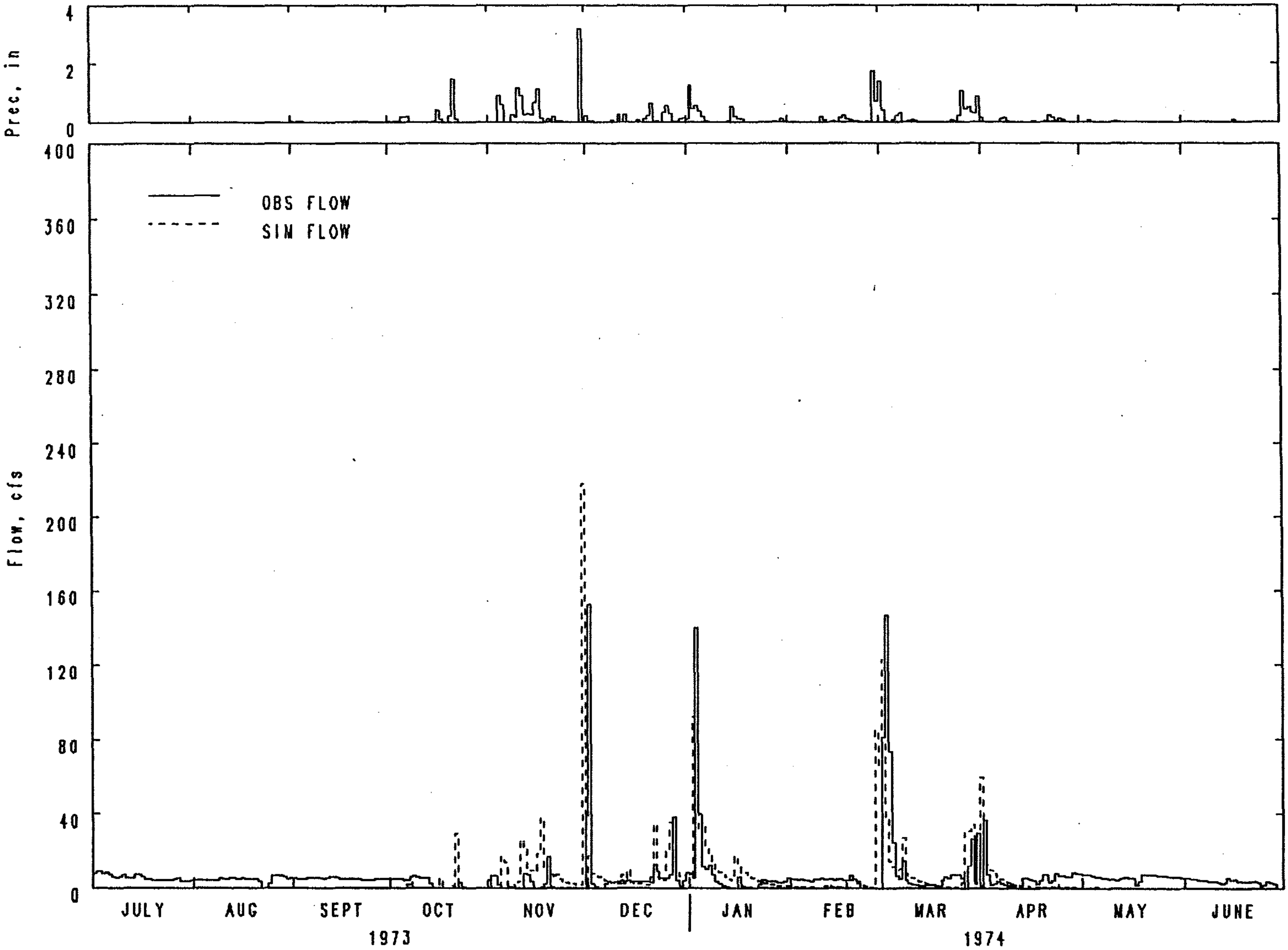
Simulated and Observed Daily Flow at Rainbow Drive, 1972-73



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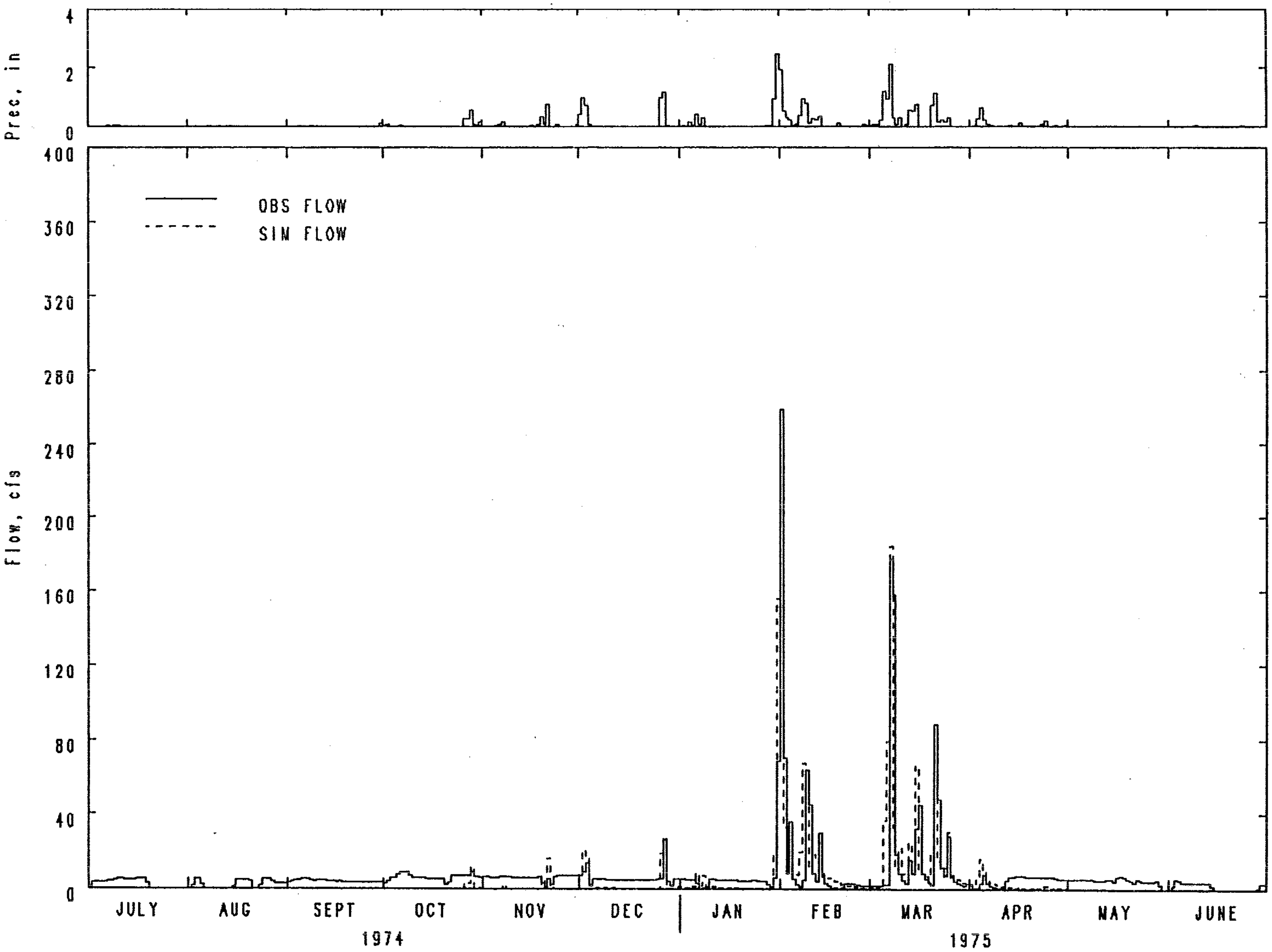
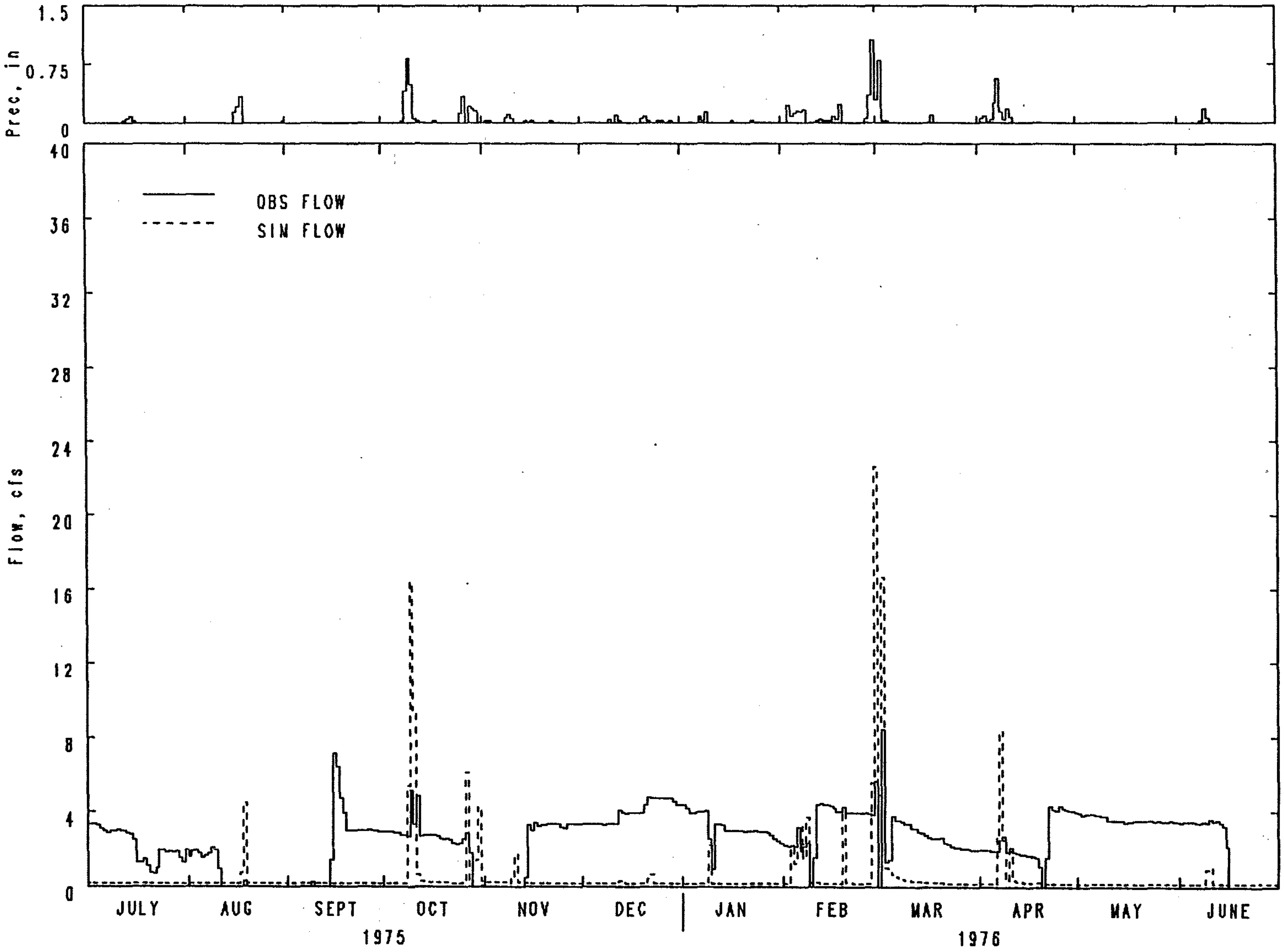
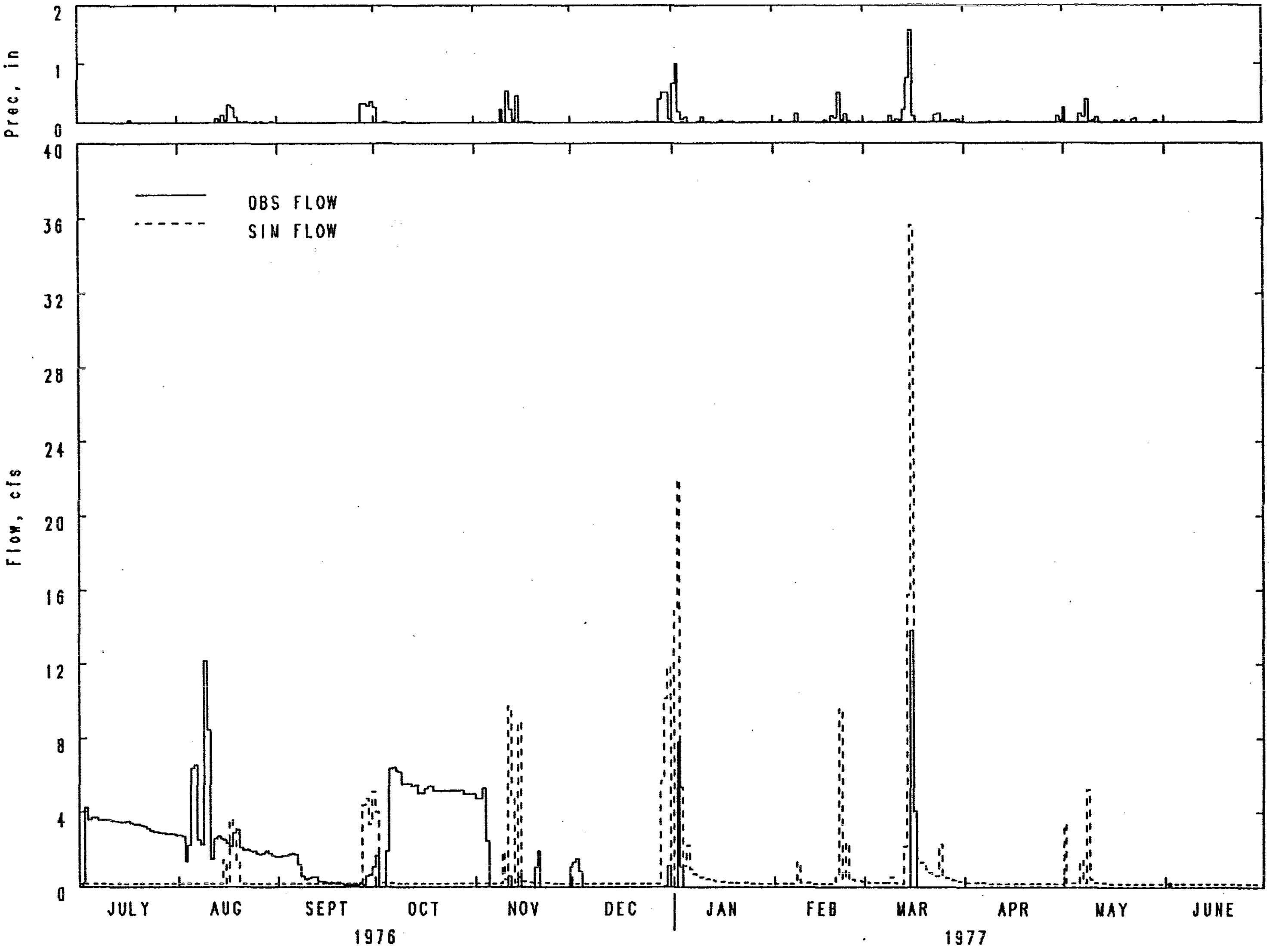
Simulated and Observed Daily Flow at Rainbow Drive, 1973-74



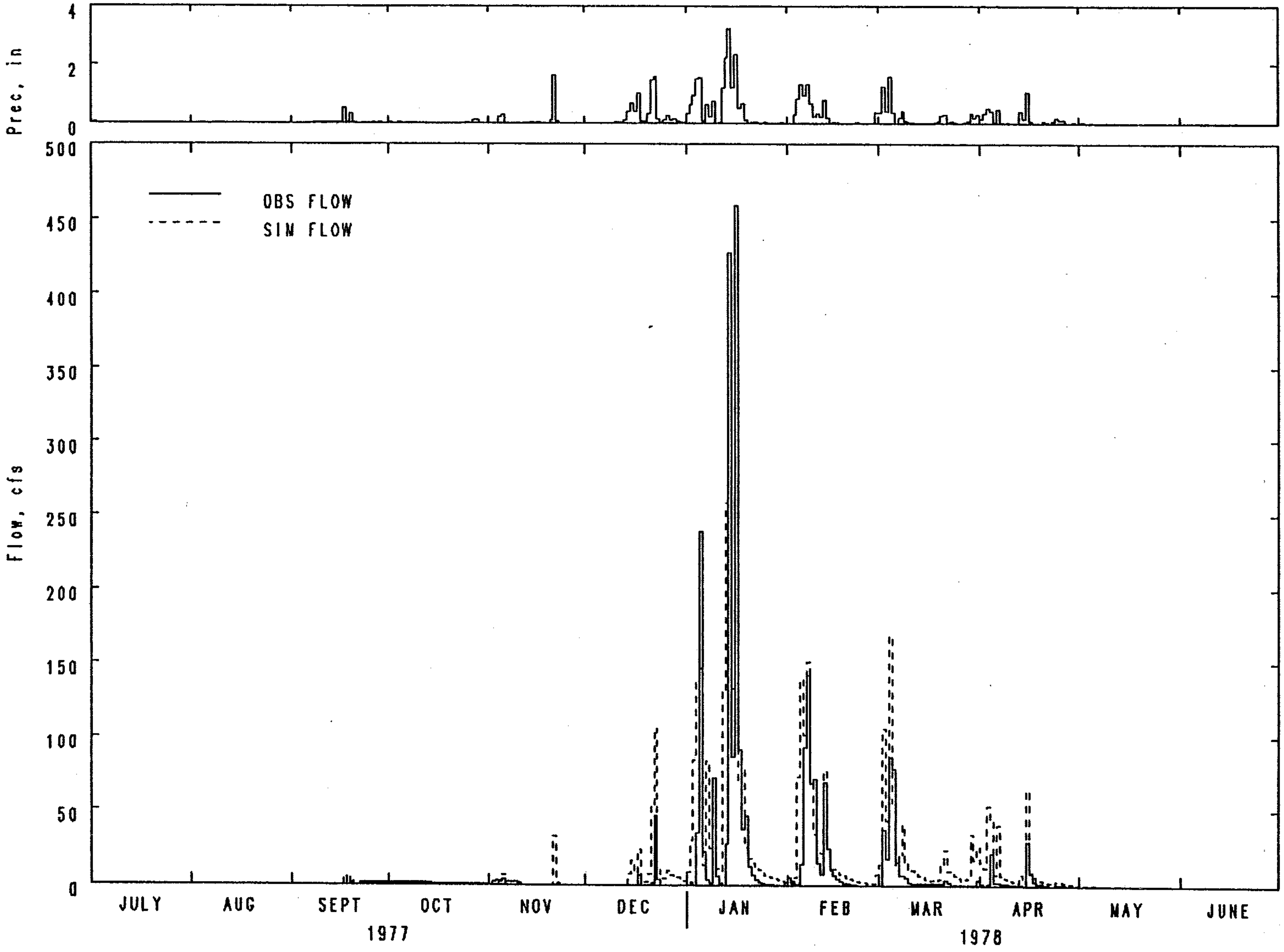
Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1974-75



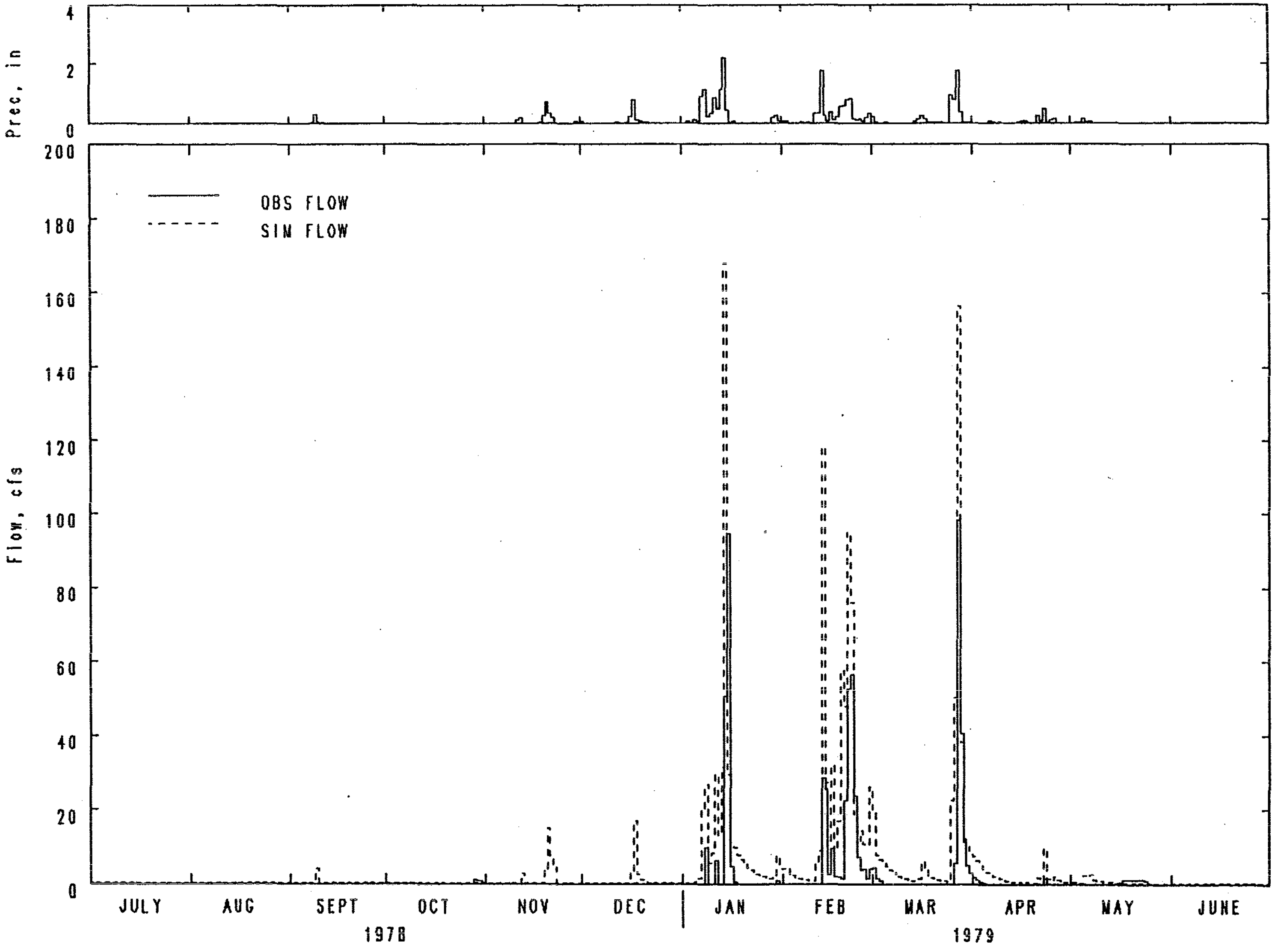
Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1975-76



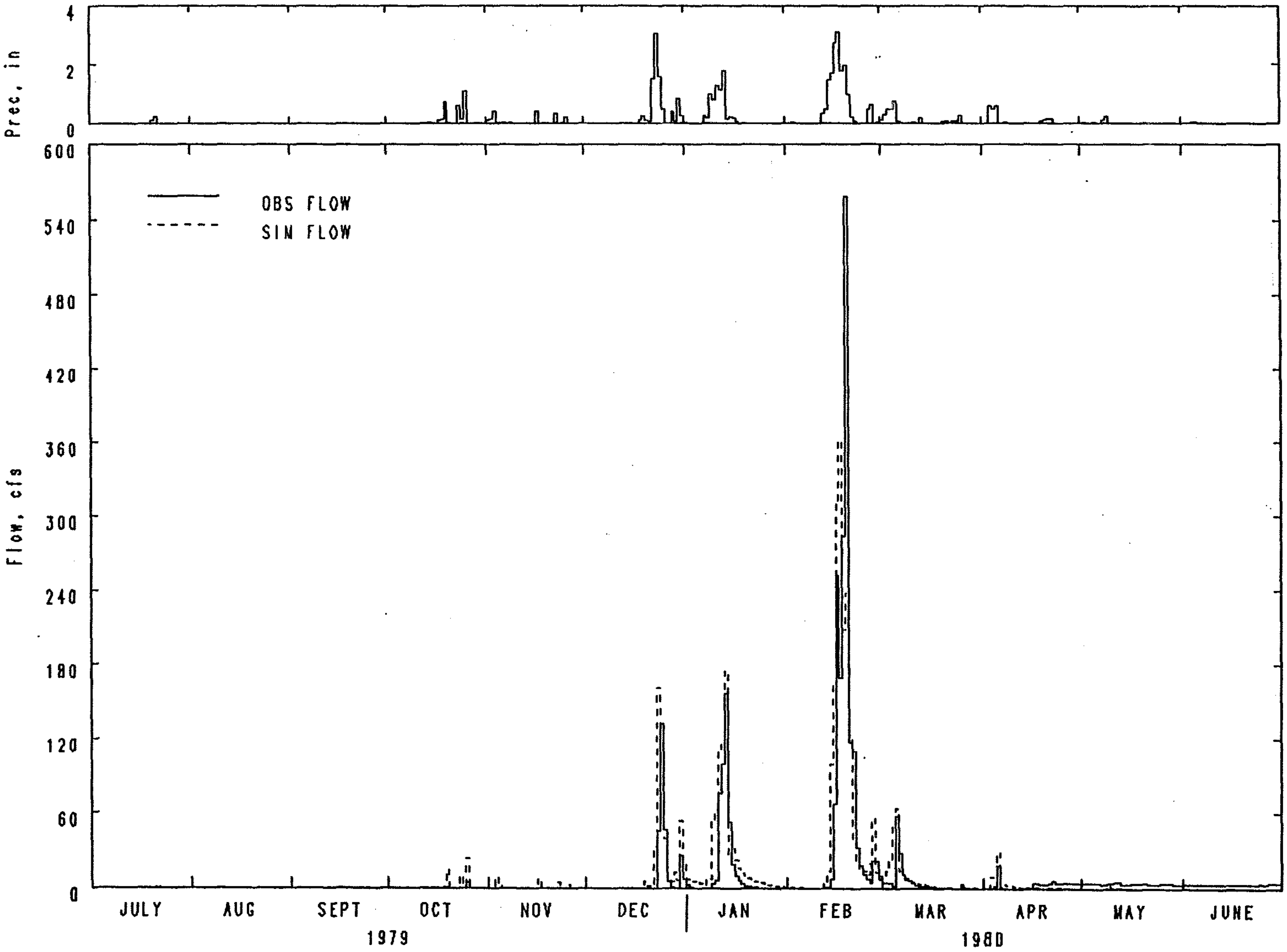
Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1976-77



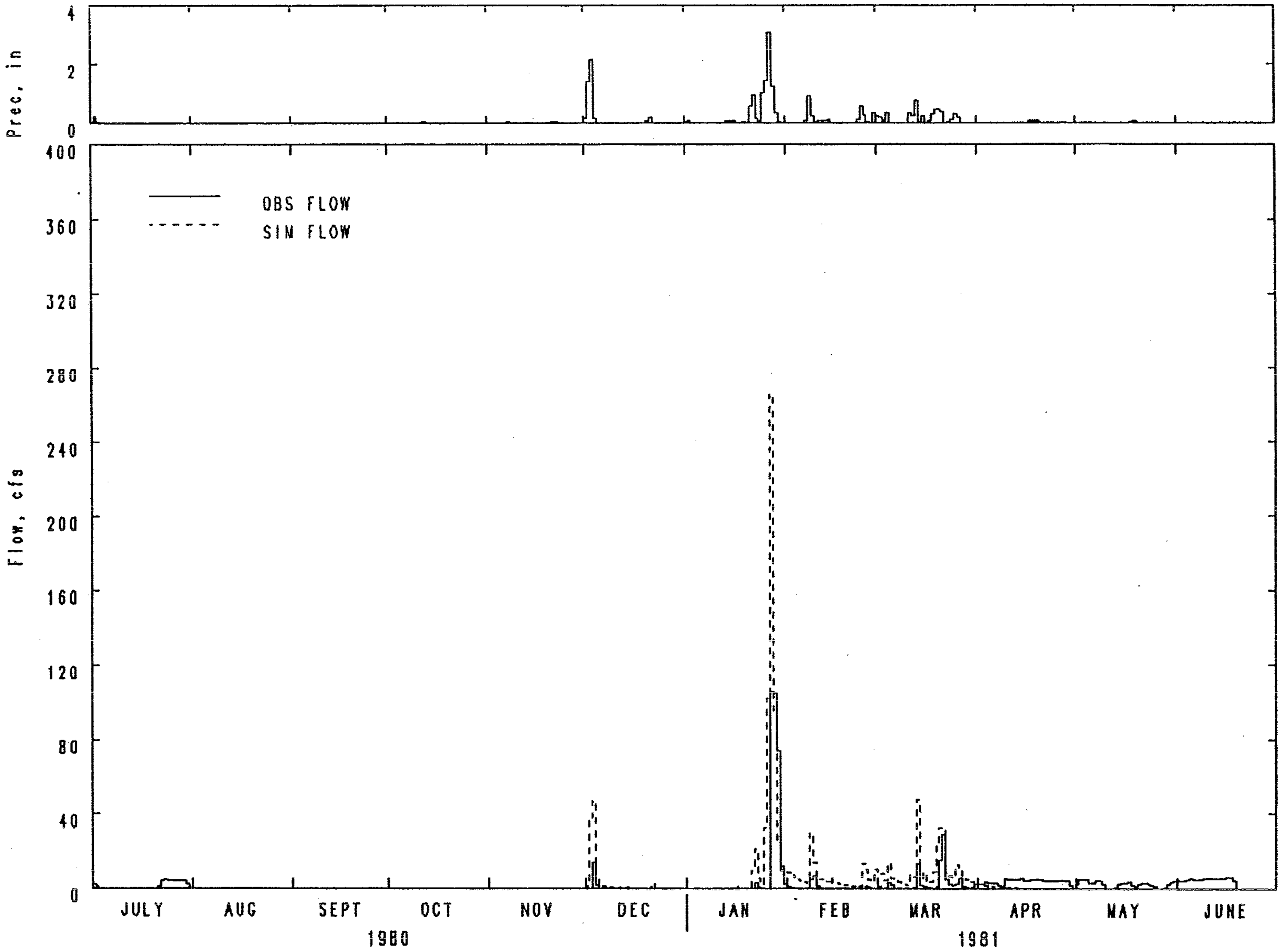
Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1977-78



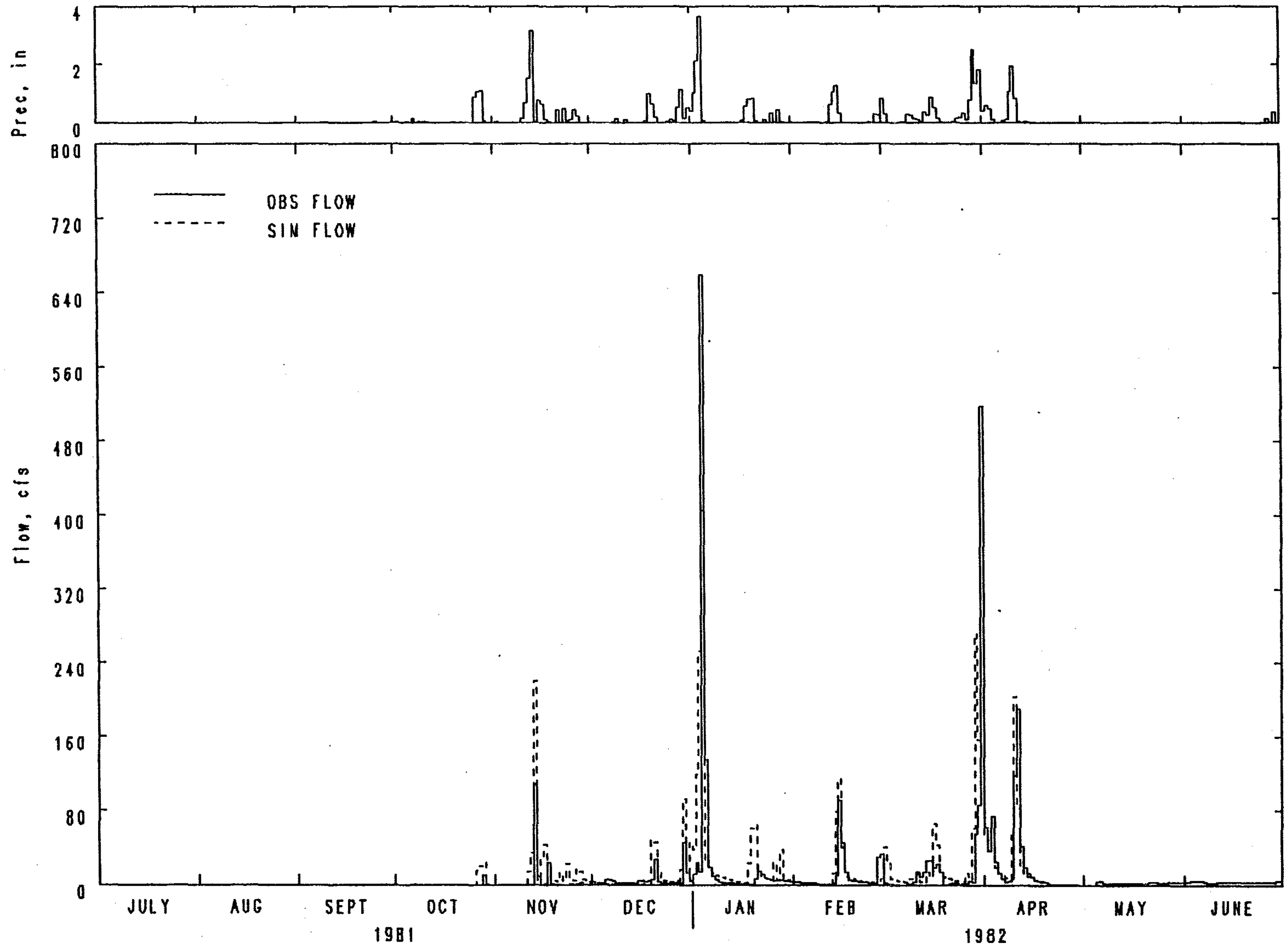
Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1978-79



Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1979-80



Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1980-81



Calabazas Creek Hydrology Verification
Simulated and Observed Daily Flow at Rainbow Drive, 1981-82

# APPENDIX B.

# FUNCTION TABLES (FTABLES) FOR ALL DETENTION BASINS AND SCENARIOS

# DETENTION BASIN NO. 1

## FLOOD CONTROL SCENARIO

```
  FTABLE     11
 ROWS COLS ***
  16    4
    DEPTH      AREA    VOLUME     DISCH     Detention Time          ***
     (FT)    (ACRES)  (AC-FT)     (CFS)     Hours             Comment ***
     0.00       3.8      0.00      0.00                 Invert Elevation
     1.00       3.9      3.82      3.58            12.9
     1.06       3.9      4.37      4.10            12.9
     1.42       4.0      5.62      6.83            10.0
     2.00       4.0      7.64      8.46            11.0
     2.36       4.1      9.00      9.56            11.4
     3.00       4.1     11.42     10.45            13.2
     4.00       4.2     15.24     11.87            15.6
     4.76       4.2     18.18     12.97            17.0
     5.00       4.3     19.11     14.41            16.1   Spillway crest
     5.10       4.3     19.54     21.58            11.0
     5.20       4.3     19.97     34.70             7.0
     5.50       4.4     21.25     94.64             2.7
     5.70       4.4     22.10    147.31             1.8
     6.00       4.5     23.39    241.34             1.2
    10.00       6.0     50.00    500.00             1.2
  END FTABLE 11
```

## WATER QUALITY POOL

```
  FTABLE     11
 ROWS COLS ***
  17    4
    DEPTH      AREA    VOLUME     DISCH     Detention Time     Comment   ***
     (FT)    (ACRES)  (AC-FT)     (CFS)     hours                        ***
     0.00       3.8      0.00      0.00                        Bottom of Pool/Basin
     2.00       3.8      7.64      0.00                        Invert Elevation/Top of Perm Pool
     3.00       3.9     11.47      3.58          38.8
     3.06       3.9     12.01      4.10          35.6
     3.42       4.0     13.27      6.83          23.6
     4.00       4.0     15.29      8.46          21.9
     4.36       4.1     16.65      9.56          21.1
     5.00       4.1     19.06     10.45          22.1
     6.00       4.2     22.89     11.87          23.4
     6.76       4.2     25.83     12.97          24.1
     7.00       4.3     26.75     14.41          22.5          Spillway Crest
     7.10       4.3     27.18     21.58          15.3
     7.20       4.3     27.61     34.70           9.6
     7.50       4.4     28.89     94.64           3.7
     7.70       4.4     29.75    147.31           2.4
     8.00       4.5     31.03    241.34           1.6
    10.00       6.0     50.00    500.00           1.6
  END FTABLE 11
```

## WATER QUALITY POOL EXTENTED DETENTION

```
  FTABLE     11
 ROWS COLS ***
  17    4
    DEPTH      AREA    VOLUME     DISCH     Detention Time     Comment ***
     (FT)    (ACRES)  (AC-FT)     (CFS)     hours                      ***
     0.00       3.8      0.00      0.00                        Bottom of Pool/Basin
     2.00       3.8      7.64      0.00                        Invert Elevation/Top of Perm Pool
     3.00       3.9     11.47      1.79          77.6
     3.06       3.9     12.01      2.05          71.1
     3.42       4.0     13.27      3.41          47.1
     4.00       4.0     15.29      4.23          43.8
     4.36       4.1     16.65      4.78          42.2
     5.00       4.1     19.06      5.23          44.2
     6.00       4.2     22.89      5.94          46.7
     6.76       4.2     25.83      6.48          48.3
     7.00       4.3     26.75      7.20          45.0
     7.10       4.3     27.18     21.58          15.3          Spillway Crest
     7.20       4.3     27.61     34.70           9.6
     7.50       4.4     28.89     94.64           3.7
     7.70       4.4     29.75    147.31           2.4
     8.00       4.5     31.03    241.34           1.6
    10.00       6.0     50.00    500.00           1.6
  END FTABLE 11
```

# DETENTION BASIN NO. 2

## FLOOD CONTROL SCENARIO

```
  FTABLE     21
 ROWS COLS ***
   16    4
     DEPTH      AREA    VOLUME     DISCH      Detention Time            ***
      (FT)   (ACRES)   (AC-FT)     (CFS)      Hours                Comment ***
      0.00       2.8      0.00      0.00                             Invert Elevation
      1.00       2.8      2.77      2.60            12.9
      1.06       2.8      3.17      2.97            12.9
      1.42       2.9      4.08      4.95            10.0
      2.00       2.9      5.54      6.13            11.0
      2.36       2.9      6.53      6.93            11.4
      3.00       3.0      8.28      7.58            13.2
      4.00       3.0     11.06      8.61            15.6
      4.76       3.1     13.19      9.41            17.0
      5.00       3.1     13.86     10.45            16.1            Spillway crest
      5.10       3.1     14.17     15.65            11.0
      5.20       3.1     14.48     25.17             7.0
      5.50       3.2     15.41     68.64             2.7
      5.70       3.2     16.03    106.84             1.8
      6.00       3.2     16.96    175.04             1.2
     10.00       5.0     30.00    300.00             1.2
  END FTABLE 21
```

## WATER QUALITY POOL

```
  FTABLE     21
 ROWS COLS ***
   17    4
     DEPTH      AREA    VOLUME     DISCH      Detention Time       Comment  ***
      (FT)   (ACRES)   (AC-FT)     (CFS)      hours                         ***
      0.00       2.8      0.00      0.00                           Bottom of Pool/Basin
      2.00       2.8      5.54      0.00                           Invert Elevation/Top of Perm Pool
      3.00       2.8      8.32      2.60            38.8
      3.06       2.8      8.71      2.97            35.6
      3.42       2.9      9.62      4.95            23.6
      4.00       2.9     11.09      6.13            21.9
      4.36       2.9     12.07      6.93            21.1
      5.00       3.0     13.83      7.58            22.1
      6.00       3.0     16.60      8.61            23.4
      6.76       3.1     18.73      9.41            24.1
      7.00       3.1     19.40     10.45            22.5          Spillway Crest
      7.10       3.1     19.71     15.65            15.3
      7.20       3.1     20.02     25.17             9.6
      7.50       3.2     20.96     68.64             3.7
      7.70       3.2     21.58    106.84             2.4
      8.00       3.2     22.51    175.04             1.6
     10.00       5.0     30.00    300.00             1.6
  END FTABLE 21
```

## WATER QUALITY POOL EXTENTED DETENTION

```
  FTABLE     21
 ROWS COLS ***
   17    4
     DEPTH      AREA    VOLUME     DISCH      Detention Time       Comment ***
      (FT)   (ACRES)   (AC-FT)     (CFS)      hours                        ***
      0.00       2.8      0.00      0.00                           Bottom of Pool/Basin
      2.00       2.8      5.54      0.00                           Invert Elevation/Top of Perm Pool
      3.00       2.8      8.32      1.30          77.6
      3.06       2.8      8.71      1.49          71.1
      3.42       2.9      9.62      2.48          47.1
      4.00       2.9     11.09      3.07          43.8
      4.36       2.9     12.07      3.47          42.2
      5.00       3.0     13.83      3.79          44.2
      6.00       3.0     16.60      4.31          46.7
      6.76       3.1     18.73      4.70          48.3
      7.00       3.1     19.40      5.22          45.0            Spillway Crest
      7.10       3.1     19.71     15.65          15.3
      7.20       3.1     20.02     25.17           9.6
      7.50       3.2     20.96     68.64           3.7
      7.70       3.2     21.58    106.84           2.4
      8.00       3.2     22.51    175.04           1.6
     10.00       5.0     30.00    300.00           1.6
  END FTABLE 21
```

# DETENTION BASIN NO. 3

## FLOOD CONTROL SCENARIO

```
  FTABLE     31
 ROWS COLS ***
   16    4
     DEPTH      AREA     VOLUME      DISCH      Detention Time          ***
      (FT)    (ACRES)   (AC-FT)      (CFS)      Hours              Comment ***
      0.00       7.1       0.00       0.00                        Invert Elevation
      1.00       7.3       7.11       6.66               12.9
      1.06       7.3       8.12       7.62               12.9
      1.42       7.4      10.46      12.69               10.0
      2.00       7.4      14.22      15.73               11.0
      2.36       7.5      16.75      17.77               11.4
      3.00       7.6      21.24      19.44               13.2
      4.00       7.8      28.35      22.09               15.6
      4.76       7.9      33.82      24.12               17.0
      5.00       8.0      35.54      26.79               16.1           Spillway crest
      5.10       8.0      36.34      40.14               11.0
      5.20       8.1      37.13      64.54                7.0
      5.50       8.1      39.52     176.01                2.7
      5.70       8.2      41.11     273.98                1.8
      6.00       8.3      43.50     448.86                1.2
     10.00      10.0      70.00     800.00                1.2
  END FTABLE 31
```

## WATER QUALITY POOL

```
  FTABLE     31
 ROWS COLS ***
   17    4
     DEPTH      AREA     VOLUME      DISCH      Detention Time     Comment   ***
      (FT)    (ACRES)   (AC-FT)      (CFS)      hours                        ***
      0.00       7.1       0.00       0.00                         Bottom of Pool/Basin
      2.00       7.1      14.22       0.00                         Invert Elevation/Top of Perm Pool

      3.00       7.3      21.33       6.66               38.8
      3.06       7.3      22.34       7.62               35.6
      3.42       7.4      24.68      12.69               23.6
      4.00       7.4      28.43      15.73               21.9
      4.36       7.5      30.96      17.77               21.1
      5.00       7.6      35.46      19.44               22.1
      6.00       7.8      42.57      22.09               23.4
      6.76       7.9      48.03      24.12               24.1
      7.00       8.0      49.76      26.79               22.5         Spillway Crest
      7.10       8.0      50.55      40.14               15.3
      7.20       8.1      51.35      64.54                9.6
      7.50       8.1      53.74     176.01                3.7
      7.70       8.2      55.33     273.98                2.4
      8.00       8.3      57.71     448.86                1.6
     10.00      10.0      70.00     800.00               1.6
  END FTABLE 31
```

## WATER QUALITY POOL EXTENTED DETENTION

```
  FTABLE     31
 ROWS COLS ***
   17    4
     DEPTH      AREA     VOLUME      DISCH      Detention Time     Comment ***
      (FT)    (ACRES)   (AC-FT)      (CFS)      hours                      ***
      0.00       7.1       0.00       0.00                         Bottom of Pool/Basin
      2.00       7.1      14.22       0.00                         Invert Elevation/Top of Perm Pool
      3.00       7.3      21.33       3.33              77.6
      3.06       7.3      22.34       3.81              71.1
      3.42       7.4      24.68       6.35              47.1
      4.00       7.4      28.43       7.86              43.8
      4.36       7.5      30.96       8.89              42.2
      5.00       7.6      35.46       9.72              44.2
      6.00       7.8      42.57      11.04              46.7
      6.76       7.9      48.03      12.06              48.3
      7.00       8.0      49.76      13.40              45.0         Spillway Crest
      7.10       8.0      50.55      40.14              15.3
      7.20       8.1      51.35      64.54               9.6
      7.50       8.1      53.74     176.01               3.7
      7.70       8.2      55.33     273.98               2.4
      8.00       8.3      57.71     448.86               1.6
     10.00      10.0      70.00     800.00               1.6
  END FTABLE 31
```

# DETENTION BASIN NO. 4

**FLOOD CONTROL SCENARIO**

```
  FTABLE     41
 ROWS COLS ***
  16    4
     DEPTH      AREA    VOLUME     DISCH    Detention Time             ***
      (FT)   (ACRES)   (AC-FT)     (CFS)    Hours                 Comment ***
      0.00       2.1      0.00      0.00                            Invert Elevation
      1.00       2.2      2.14      2.01           12.9
      1.06       2.2      2.45      2.30           12.9
      1.42       2.2      3.15      3.83           10.0
      2.00       2.2      4.28      4.74           11.0
      2.36       2.3      5.05      5.36           11.4
      3.00       2.3      6.40      5.86           13.2
      4.00       2.3      8.54      6.66           15.6
      4.76       2.4     10.19      7.27           17.0
      5.00       2.4     10.71      8.07           16.1          Spillway crest
      5.10       2.4     10.95     12.09           11.0
      5.20       2.4     11.19     19.45            7.0
      5.50       2.4     11.91     53.04            2.7
      5.70       2.5     12.39     82.56            1.8
      6.00       2.5     13.11    135.25            1.2
     10.00       4.0     25.00    250.00            1.2
  END FTABLE 41
```

**WATER QUALITY POOL**

```
  FTABLE     41
 ROWS COLS ***
  17    4
     DEPTH      AREA    VOLUME     DISCH    Detention Time        Comment  ***
      (FT)   (ACRES)   (AC-FT)     (CFS)    hours                         ***
      0.00       2.1      0.00      0.00                          Bottom of Pool/Basin
      2.00       2.1      4.28      0.00                          Invert Elevation/Top of Perm Pool

      3.00       2.2      6.43      2.01           38.8
      3.06       2.2      6.73      2.30           35.6
      3.42       2.2      7.44      3.83           23.6
      4.00       2.2      8.57      4.74           21.9
      4.36       2.3      9.33      5.36           21.1
      5.00       2.3     10.68      5.86           22.1
      6.00       2.3     12.83      6.66           23.4
      6.76       2.4     14.47      7.27           24.1
      7.00       2.4     14.99      8.07           22.5        Spillway Crest
      7.10       2.4     15.23     12.09           15.3
      7.20       2.4     15.47     19.45            9.6
      7.50       2.4     16.19     53.04            3.7
      7.70       2.5     16.67     82.56            2.4
      8.00       2.5     17.39    135.25            1.6
     10.00       4.0     25.00    250.00            1.6
  END FTABLE 41
```

**WATER QUALITY POOL EXTENTED DETENTION**

```
  FTABLE     41
 ROWS COLS ***
  17    4
     DEPTH      AREA    VOLUME     DISCH    Detention Time        Comment ***
      (FT)   (ACRES)   (AC-FT)     (CFS)    hours                         ***
      0.00       2.1      0.00      0.00                          Bottom of Pool/Basin
      2.00       2.1      4.28      0.00                          Invert Elevation/Top of Perm Pool

      3.00       2.2      6.43      1.00         77.6
      3.06       2.2      6.73      1.15         71.1
      3.42       2.2      7.44      1.91         47.1
      4.00       2.2      8.57      2.37         43.8
      4.36       2.3      9.33      2.68         42.2
      5.00       2.3     10.68      2.93         44.2
      6.00       2.3     12.83      3.33         46.7
      6.76       2.4     14.47      3.63         48.3
      7.00       2.4     14.99      4.04         45.0          Spillway Crest
      7.10       2.4     15.23     12.09         15.3
      7.20       2.4     15.47     19.45          9.6
      7.50       2.4     16.19     53.04          3.7
      7.70       2.5     16.67     82.56          2.4
      8.00       2.5     17.39    135.25          1.6
     10.00       4.0     25.00    250.00          1.6
  END FTABLE 41
```

# DETENTION BASIN NO. 5

**FLOOD CONTROL SCENARIO**

```
  FTABLE     51
 ROWS COLS ***
   16    4
     DEPTH      AREA     VOLUME     DISCH     Detention Time            ***
      (FT)    (ACRES)   (AC-FT)     (CFS)     Hours               Comment  ***
      0.00       2.9      0.00       0.00                           Invert Elevation
      1.00       3.0      2.92       2.74           12.9
      1.06       3.0      3.34       3.13           12.9
      1.42       3.0      4.30       5.21           10.0
      2.00       3.1      5.84       6.46           11.0
      2.36       3.1      6.88       7.30           11.4
      3.00       3.1      8.72       7.98           13.2
      4.00       3.2     11.64       9.07           15.6
      4.76       3.2     13.89       9.90           17.0
      5.00       3.3     14.59      11.00           16.1              Spillway crest
      5.10       3.3     14.92      16.48           11.0
      5.20       3.3     15.25      26.50            7.0
      5.50       3.3     16.23      72.28            2.7
      5.70       3.4     16.88     112.51            1.8
      6.00       3.4     17.86     184.32            1.2
     10.00       5.0     30.00     300.00            1.2
  END FTABLE 51
```

**WATER QUALITY POOL**

```
  FTABLE     51
 ROWS COLS ***
   17    4
     DEPTH      AREA     VOLUME     DISCH     Detention Time      Comment  ***
      (FT)    (ACRES)   (AC-FT)     (CFS)     hours                        ***
      0.00       2.9      0.00       0.00                         Bottom of Pool/Basin
      2.00       2.9      5.84       0.00                         Invert Elevation/Top of Perm Pool

      3.00       3.0      8.76       2.74           38.8
      3.06       3.0      9.17       3.13           35.6
      3.42       3.0     10.13       5.21           23.6
      4.00       3.1     11.68       6.46           21.9
      4.36       3.1     12.71       7.30           21.1
      5.00       3.1     14.56       7.98           22.1
      6.00       3.2     17.48       9.07           23.4
      6.76       3.2     19.72       9.90           24.1
      7.00       3.3     20.43      11.00           22.5            Spillway Crest
      7.10       3.3     20.76      16.48           15.3
      7.20       3.3     21.09      26.50            9.6
      7.50       3.3     22.07      72.28            3.7
      7.70       3.4     22.72     112.51            2.4
      8.00       3.4     23.70     184.32            1.6
     10.00       5.0     30.00     300.00            1.6
  END FTABLE 51
```

**WATER QUALITY POOL EXTENTED DETENTION**

```
  FTABLE     51
 ROWS COLS ***
   17    4
     DEPTH      AREA     VOLUME     DISCH     Detention Time      Comment ***
      (FT)    (ACRES)   (AC-FT)     (CFS)     hours                       ***
      0.00       2.9      0.00       0.00                         Bottom of Pool/Basin
      2.00       2.9      5.84       0.00                         Invert Elevation/Top of Perm
      3.00       3.0      8.76       1.37         77.6
      3.06       3.0      9.17       1.56         71.1
      3.42       3.0     10.13       2.61         47.1
      4.00       3.1     11.68       3.23         43.8
      4.36       3.1     12.71       3.65         42.2
      5.00       3.1     14.56       3.99         44.2
      6.00       3.2     17.48       4.53         46.7
      6.76       3.2     19.72       4.95         48.3
      7.00       3.3     20.43       5.50         45.0           Spillway Crest
      7.10       3.3     20.76      16.48         15.3
      7.20       3.3     21.09      26.50          9.6
      7.50       3.3     22.07      72.28          3.7
      7.70       3.4     22.72     112.51          2.4
      8.00       3.4     23.70     184.32          1.6
     10.00       5.0     30.00     300.00          1.6
  END FTABLE 51
```

# DETENTION BASIN NO. 6

**FLOOD CONTROL SCENARIO**

```
  FTABLE     61
 ROWS COLS ***
   16    4
     DEPTH      AREA    VOLUME     DISCH      Detention Time               ***
      (FT)   (ACRES)   (AC-FT)     (CFS)      Hours                Comment   ***
      0.00       0.6      0.00      0.00                             Invert Elevation
      1.00       0.6      0.63      0.59               12.9
      1.06       0.6      0.72      0.67               12.9
      1.42       0.7      0.93      1.13               10.0
      2.00       0.7      1.26      1.39               11.0
      2.36       0.7      1.48      1.58               11.4
      3.00       0.7      1.88      1.72               13.2
      4.00       0.7      2.51      1.96               15.6
      4.76       0.7      3.00      2.14               17.0
      5.00       0.7      3.15      2.37               16.1           Spillway crest
      5.10       0.7      3.22      3.56               11.0
      5.20       0.7      3.29      5.72                7.0
      5.50       0.7      3.50     15.60                2.7
      5.70       0.7      3.64     24.28                1.8
      6.00       0.7      3.85     39.78                1.2
     10.00       1.5      7.00     80.00                1.2
  END FTABLE 61
```

**WATER QUALITY POOL**

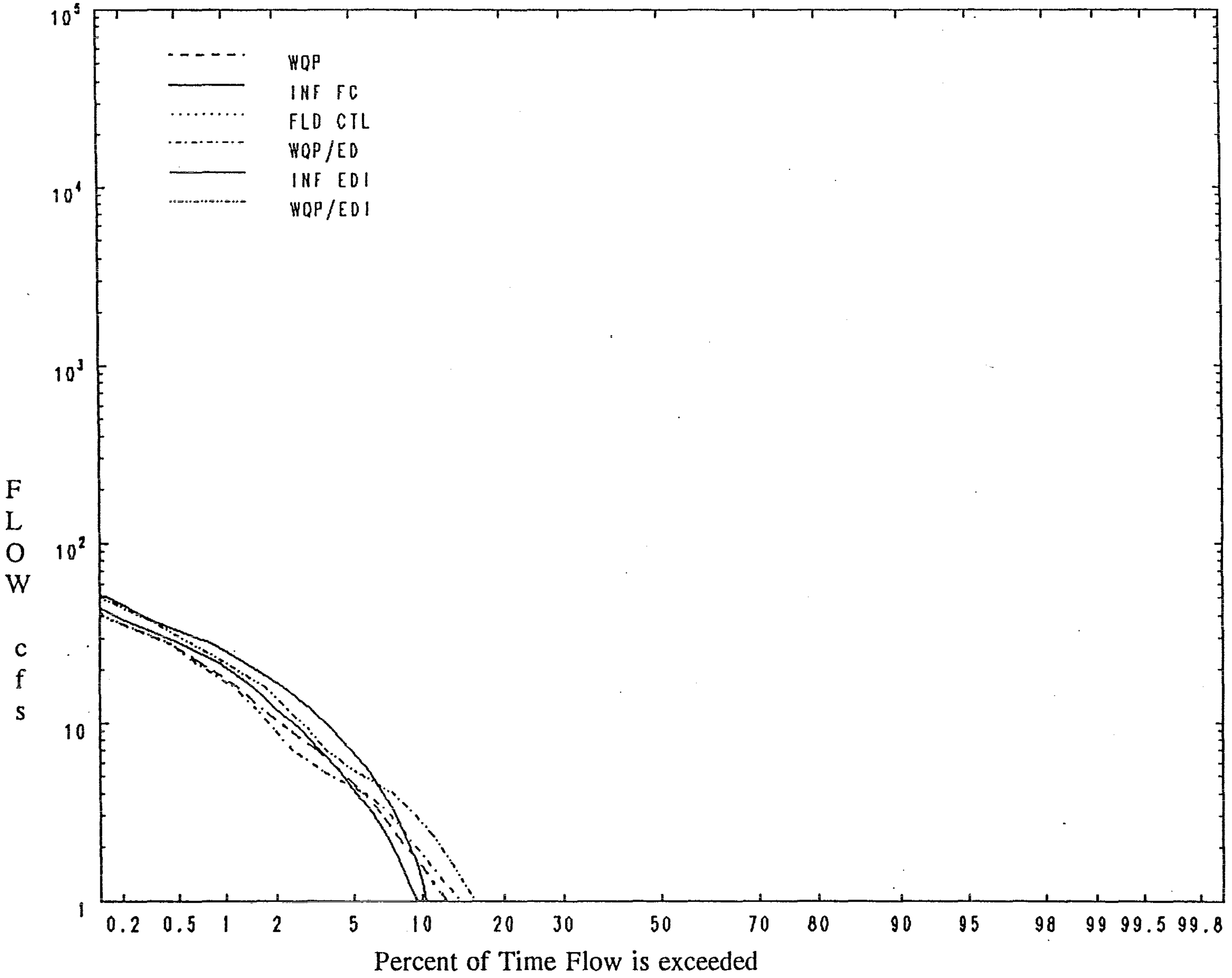
```
  FTABLE     61
 ROWS COLS ***
   17    4
     DEPTH      AREA    VOLUME     DISCH      Detention Time     Comment   ***
      (FT)   (ACRES)   (AC-FT)     (CFS)      hours                        ***
      0.00       0.6      0.00      0.00                         Bottom of Pool/Basin
      2.00       0.6      1.26      0.00                         Invert Elevation/Top of Perm Pool
      3.00       0.6      1.89      0.59               38.8
      3.06       0.6      1.98      0.67               35.6
      3.42       0.7      2.19      1.13               23.6
      4.00       0.7      2.52      1.39               21.9
      4.36       0.7      2.74      1.58               21.1
      5.00       0.7      3.14      1.72               22.1
      6.00       0.7      3.77      1.96               23.4
      6.76       0.7      4.26      2.14               24.1
      7.00       0.7      4.41      2.37               22.5       Spillway Crest
      7.10       0.7      4.48      3.56               15.3
      7.20       0.7      4.55      5.72                9.6
      7.50       0.7      4.76     15.60                3.7
      7.70       0.7      4.90     24.28                2.4
      8.00       0.7      5.11     39.78                1.6
     10.00       1.5      7.00     80.00                1.6
  END FTABLE 61
```

**WATER QUALITY POOL EXTENTED DETENTION**

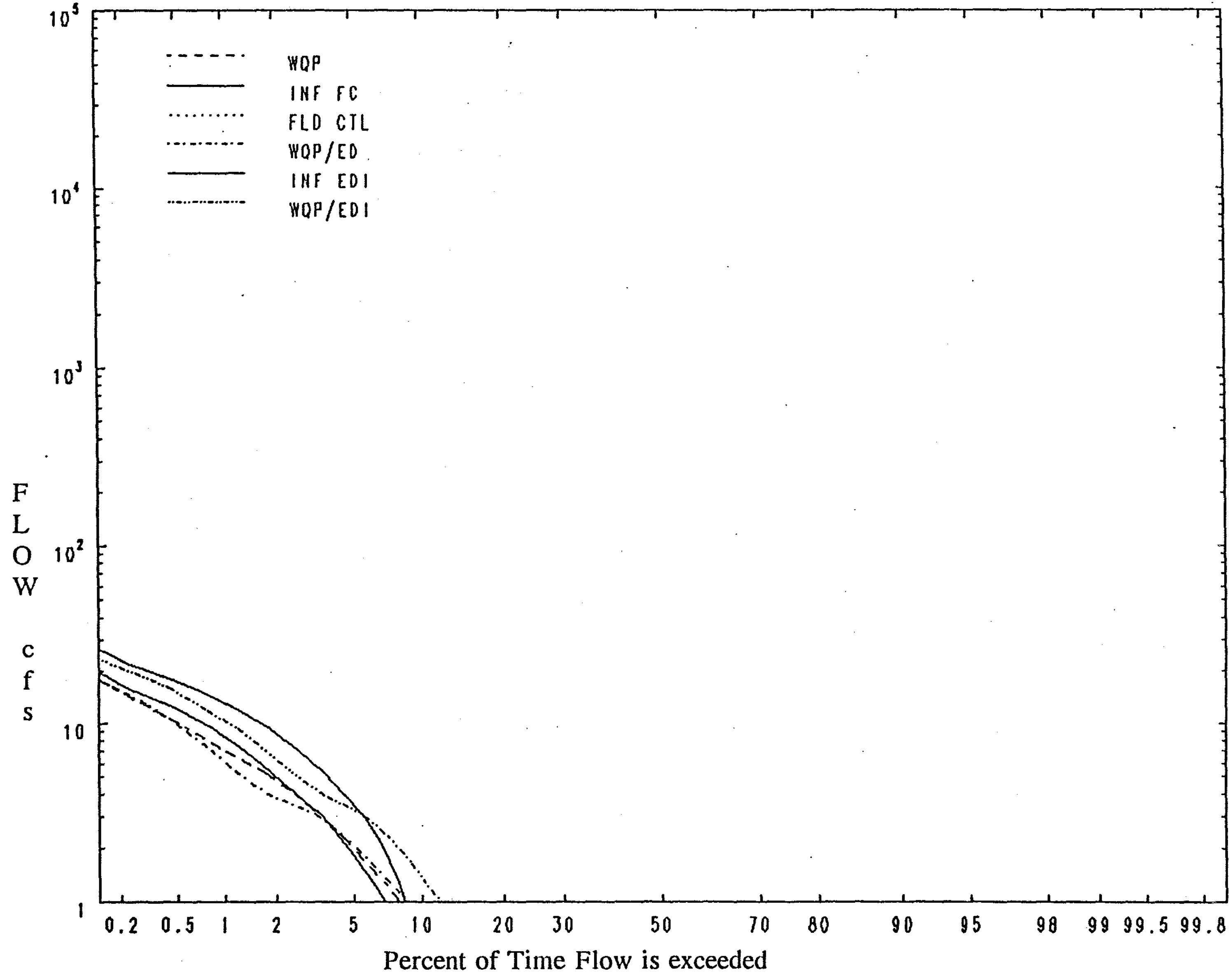
```
  FTABLE     61
 ROWS COLS ***
   17    4
     DEPTH      AREA    VOLUME     DISCH      Detention Time     Comment   ***
      (FT)   (ACRES)   (AC-FT)     (CFS)      hours                        ***
      0.00       0.6      0.00      0.00                         Bottom of Pool/Basin
      2.00       0.6      1.26      0.00                         Invert Elevation/Top of Perm
      3.00       0.6      1.89      0.30             77.6
      3.06       0.6      1.98      0.34             71.1
      3.42       0.7      2.19      0.56             47.1
      4.00       0.7      2.52      0.70             43.8
      4.36       0.7      2.74      0.79             42.2
      5.00       0.7      3.14      0.86             44.2
      6.00       0.7      3.77      0.98             46.7
      6.76       0.7      4.26      1.07             48.3
      7.00       0.7      4.41      1.19             45.0         Spillway Crest
      7.10       0.7      4.48      3.56             15.3
      7.20       0.7      4.55      5.72              9.6
      7.50       0.7      4.76     15.60              3.7
      7.70       0.7      4.90     24.28              2.4
      8.00       0.7      5.11     39.78              1.6
     10.00       1.5      7.00     80.00              1.6
  END FTABLE 61
```

# APPENDIX C.

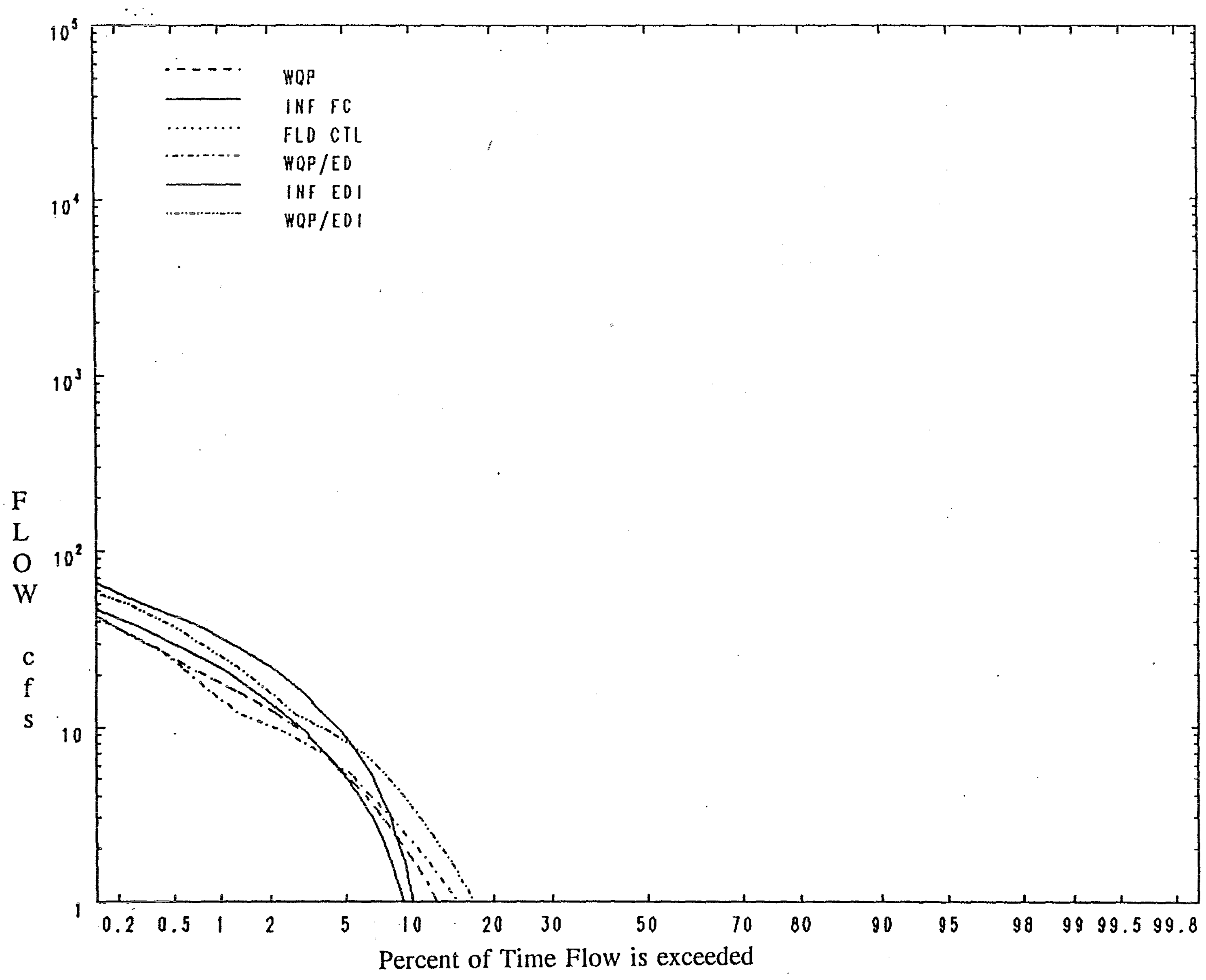
# DAILY INFLOW AND OUTFLOW FREQUENCIES FOR ALL DETENTION BASINS AND SCENARIOS



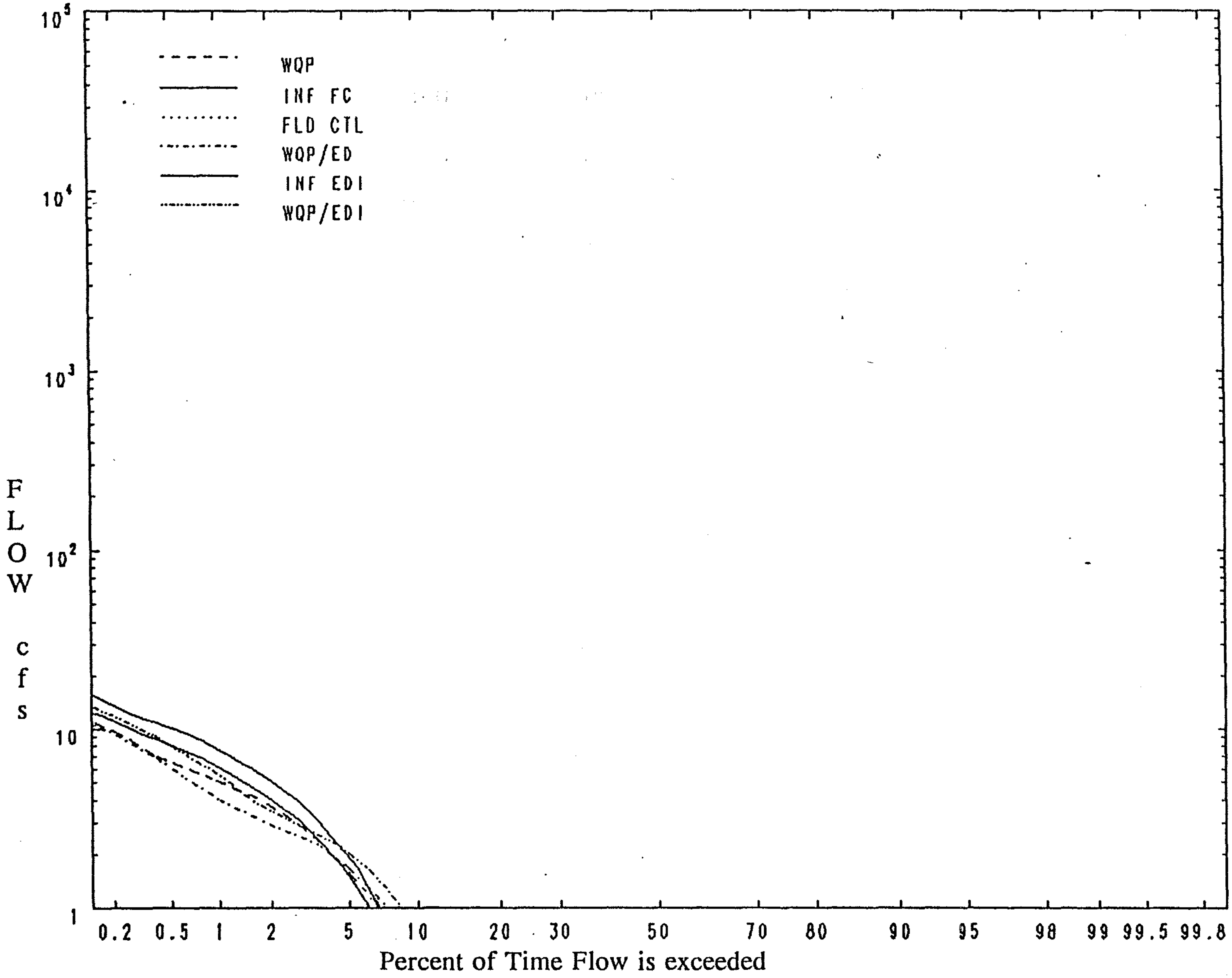
Daily Flow Frequencies for Inflow and Outflow to Detention Basin No. 1 for All Scenarios



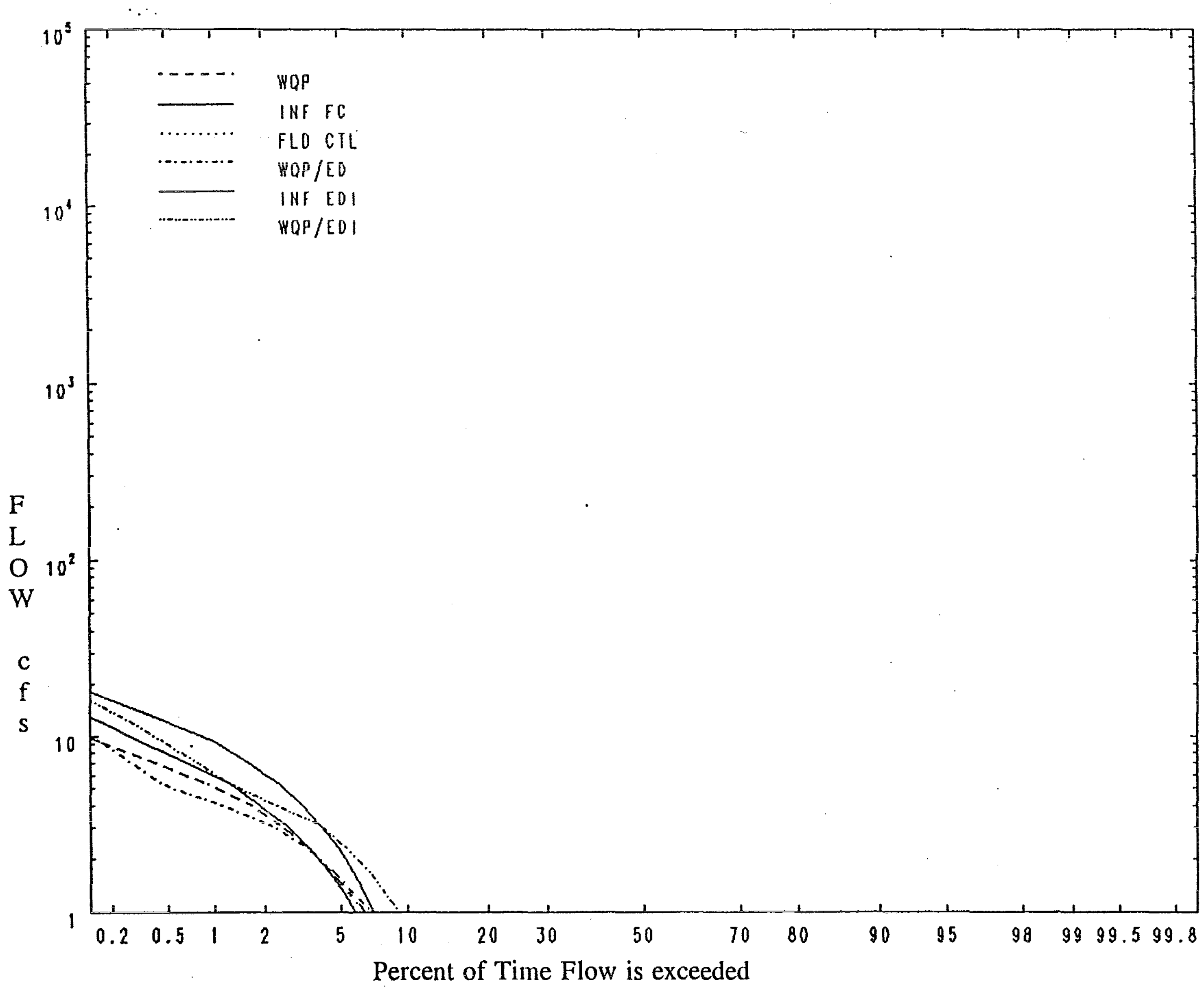
Daily Flow Frequencies for Inflow and Outflow to Detention Basin No. 2 for All Scenarios



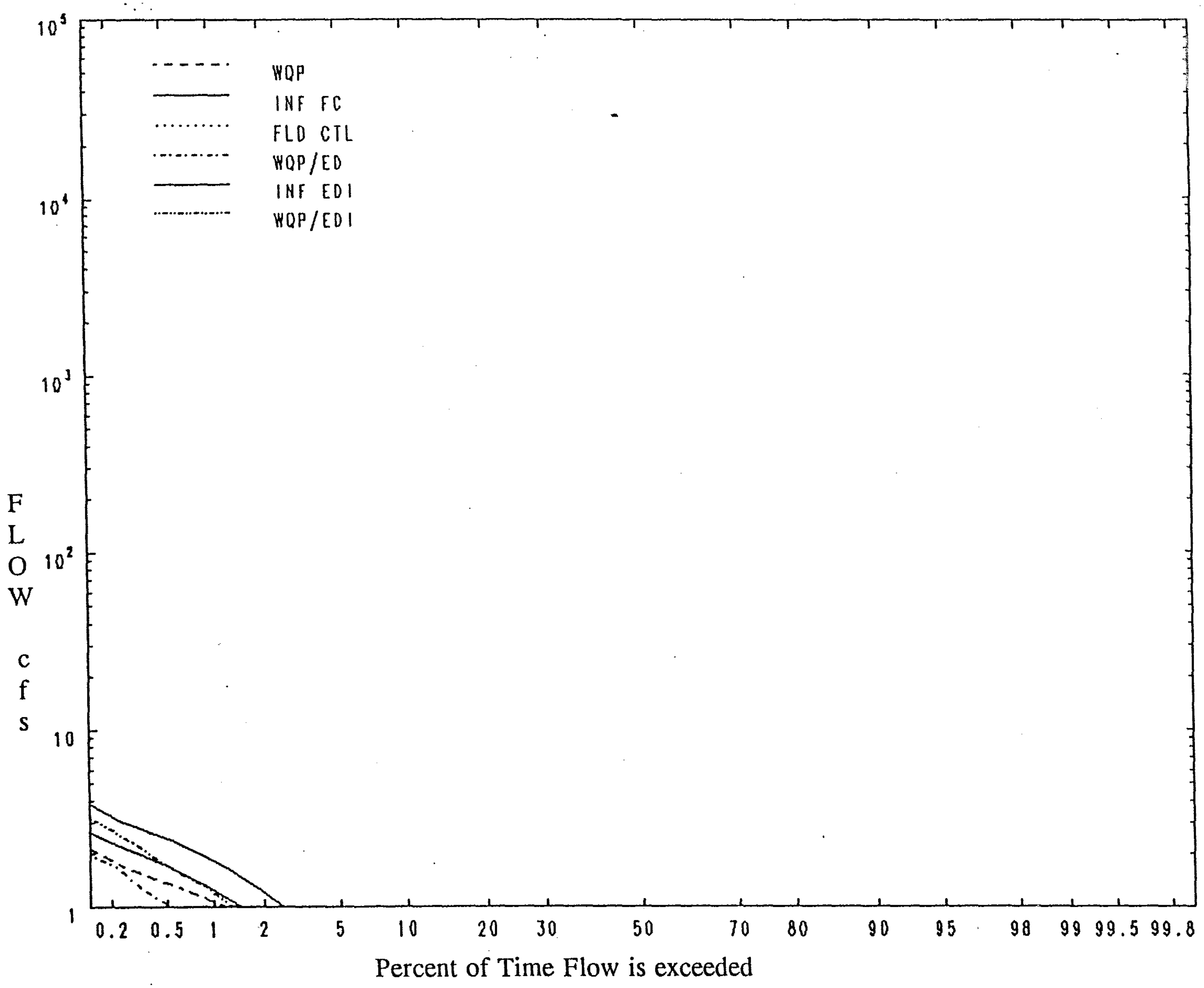
Daily Flow Frequencies for Inflow and Outflow to Detention Basin No. 3 for All Scenarios



Daily Flow Frequencies for Inflow and Outflow to Detention Basin No. 4 for All Scenarios



Daily Flow Frequencies for Inflow and Outflow to Detention Basin No. 5 for All Scenarios



Daily Flow Frequencies for Inflow and Outflow to Detention Basin No. 6 for All Scenarios